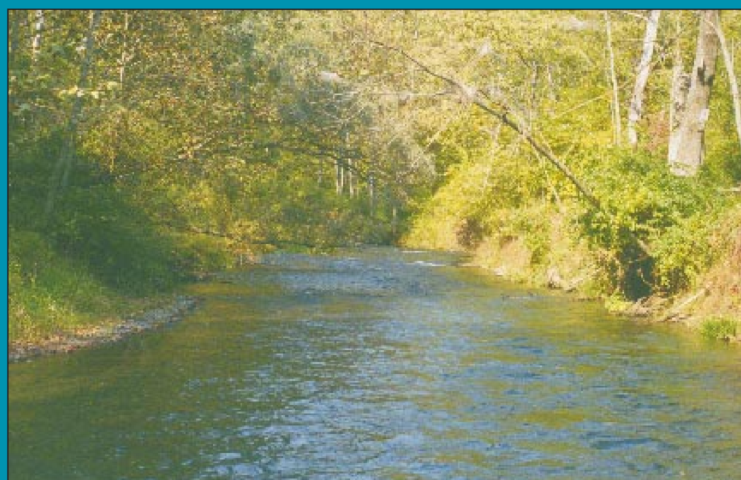
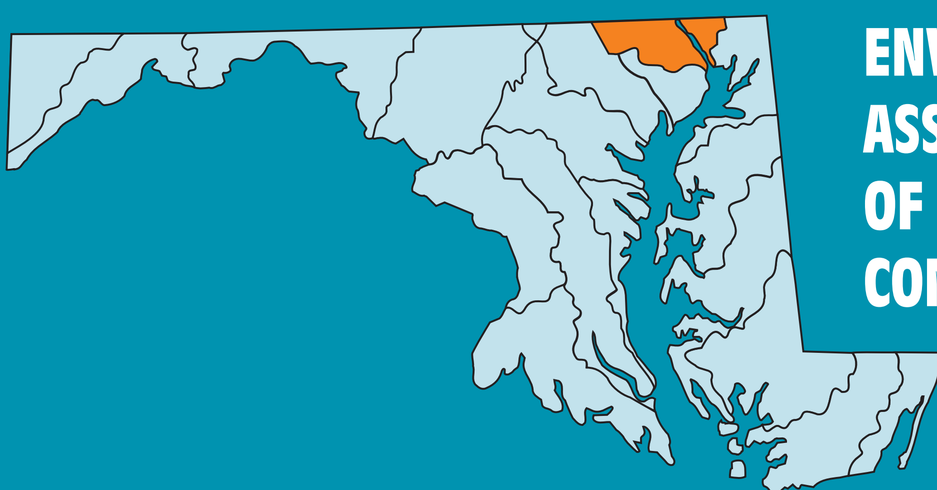
LOWER SUSQUEHANNA BASIN





ENVIRONMENTAL ASSESSMENT OF STREAM CONDITIONS

CHESAPEAKE BAY AND WATERSHED PROGRAMS
MONITORING AND NON-TIDAL ASSESSMENT
CBWP-MANTA- EA-99-10

Parris N. Glendening
Governor

Kathleen K. Townsend
Lieutenant Governor

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LOWER SUSQUEHANNA BASIN

ENVIRONMENTAL ASSESSMENT OF STREAM CONDITIONS

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Daniel M. Boward

September 1999

Maryland Department of Natural Resources
Resource Assessment Service
Monitoring and Non-Tidal Assessment Division
580 Taylor Avenue
Annapolis, MD 21401

Governor Parris N. Glendening

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FOREWORD

The Maryland Department of Natural Resources (MDNR), Monitoring and Non-tidal Assessment Division prepared this report with financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the National Oceanic and Atmospheric Administration (NOAA). The report was funded in part by MDNR's Coastal Zone Management Program pursuant to NOAA Award No. NA770Z0188. In addition to this report, basin reports are also being prepared for the Potomac Washington Metro, Ocean/Coastal, West Chesapeake, and Pocomoke basins as part of this project.

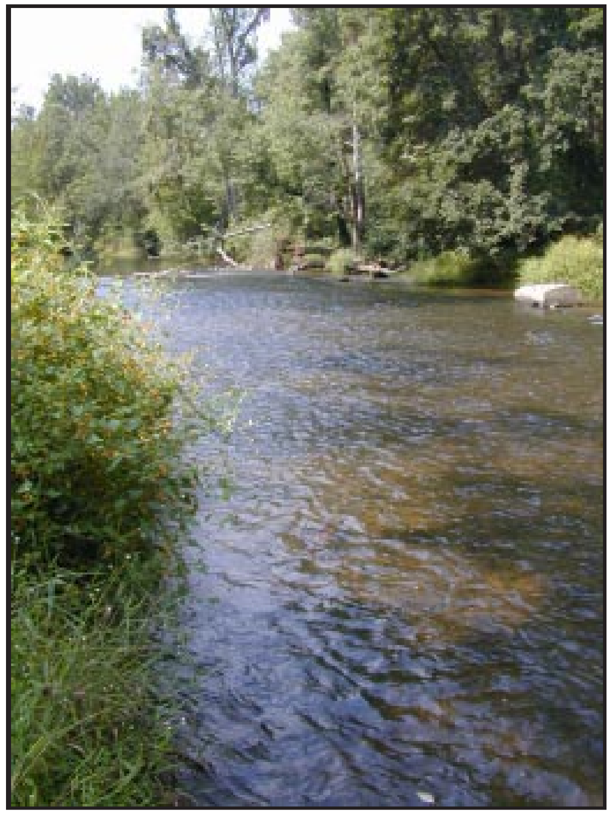
On the cover. Deer Creek in Harford County.
Photo by Scott Stranko

Much of this report is based on results of the Maryland Biological Stream Survey (MBSS), a program funded primarily by the Power Plant Research Program and administered by the Maryland Department of Natural Resources. Field data for the Lower Susquehanna basin were collected by the Maryland Department of Natural Resources. Analyses of water chemistry samples were conducted by the University of Maryland's Appalachian Laboratory (AL) under Contract No. MA97-001-003. Much of the initial data analysis for this report was conducted by Versar, Inc. under Contract No. PR-96-055-001\PRFP44 to MDNR's Power Plant Assessment Division.

This report helps fulfill two outcomes in MDNR's Strategic Plan: 1) A Vital and Life Sustaining Chesapeake Bay and Its Tributaries, and 2) Sustainable Populations of Living Resources and Healthy Ecosystems.

ACKNOWLEDGMENTS

We are grateful to Scott Stranko, Natasha Davis, Brenda Morgan, Luke Shaffer, Helen Dail, Derek Wiley, John McCadden, and Chris Mazzulli for their work in the field. We are also grateful to Katie Meagher of AL for long hours and weekends spent in the laboratory to ensure that holding times and quality control measures were met for water samples. We thank Janis Chaillou and the Versar landowner permission crew for ensuring that permissions to sample streams on private property were obtained in a timely fashion. We also thank MDNR's Marty Hurd for providing Geographic Information Systems (GIS) support. We are also grateful to Ron Klauda and John McCoy of MDNR, Michele Dobson of the Harford County Department of Public Works, and Phyllis Kilby of the Cecil County Government for editing; and Lamar Platt and Dung Nguyen for cover design.



Deer Creek, Harford County Maryland.
Photo by Dan Boward

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EXECUTIVE SUMMARY

The Maryland Biological Stream Survey (MBSS) is a statewide probablility-based survey of first, second, and third-order streams conducted by the Maryland Department of Natural Resources (MDNR). The survey is designed to characterize current biological and habitat conditions and provide a basis for assessing future trends in Maryland streams. Results of the study will provide a means to assess water quality and habitat problems, and define areas of high ecological value. This information can then be used to develop watershed-specific strategies for restoring water quality in the Chesapeake Bay drainage, and prioritize areas in need of protection.

The primary purpose of this report is to describe existing aquatic resource conditions in first, second, and third-order non-tidal streams of the Lower Susquehanna basin during 1997. All data were collected and analyzed using MBSS protocols and techniques detailed in Kazyak (1996) .

WATER QUALITY

- No stream miles in the basin had dissolved oxygen (DO) levels below the state water quality criterion of 5.0 mg/L.

- No stream miles within the basin fell below a pH of 5.0 and approximately 94% were greater than 6.0. Similarly there were no poorly-buffered streams. All sites maintained acid neutralizing capacity (ANC) greater than 200 μeq/L.

- High nitrate levels (>1.0 mg/L) were found in 94% of the stream miles sampled, indicating excessive nutrient enrichment from groundwater andsurface runoff.

- Eighty-seven percent of the stream miles had dissolved organic carbon (DOC) levels less than 5mg/L. The remaining 13% had concentrations between 5 and 10 mg/L.

PHYSICAL HABITAT

- Instream habitat.was rated Fair or Good in nearly ninety-five percent of the basin's stream miles. No streams miles were rated Very Poor.

- Thirty-two percent of stream miles had degraded or unstable banks.

- Forested buffers account for approximately 51% of the basin's riparian zone and about 30% of the stream miles had forested buffers greater than 50 meters wide. However, an estimated one-quarter of stream miles had unvegetated buffers.

FISH

- Fish were collected at 32 of the 35 sites sampled by the MBSS in 1997.

- Forty-seven fish species representing 12 families have been collected since 1994, including five gamefish species: brook trout, brown trout, rainbow trout, smallmouth bass, and largemouth bass. One species collected, logperch, are listed as rare, threatened, or endangered in Maryland.

- The estimated population of fish in first, second, and third-order streams was 3,670,261, the most abundant of which were blacknose dace with an estimated 987,171 individuals

- Fish species richness was among highest of the State's eighteen major river basins. The average number of fish species in each 75 meter segment was 14.

- Basin-wide population estimates for individual species ranged from less than 100 individuals for gizzard shad to approximately one million individuals per mile for blacknose dace.

- Eleven of the forty-seven fish species captured are not native to the Chesapeake Bay drainage. This includes: brown trout, rainbow trout, carp, largemouth bass, smallmouth bass, channel catfish, rock bass, bluegill, green sunfish, banded killifish, and banded darter.

BENTHIC MACROINVERTEBRATES

- One hundred-eleven genera of benthic macroinvertebrates were collected. The total number of taxa per site ranged from 8 to 29.

- Dominant taxa and their respective percent occurrence (among all sites in the basin) were: *Ephemerella* (a burrowing mayfly; 86%), *Cricotopus/ Orthocladius* (non-biting midges; 78%), *Prosimulium* (a blackfly;76%), *Cheumatopsyche* and *Hydropsyche* (both filter-feeding caddisflies; 73%) and *Stenonema* a mayfly; 68%).

INDEX OF BIOTIC INTEGRITY

- Fish and benthic macroinvertebrate indices of biotic integrity provided a Good or Fair rating of 50 and 85 percent of the stream miles, respectively. However, the majority of sites within the Fair category of each IBI scored within the lower range of that category and are susceptible to being degraded to Poor condition. This suggests that although biological impairment is not currently widespread, conditions exist that may quickly result in biotic degradation.

REPTILES AND AMPHIBIANS

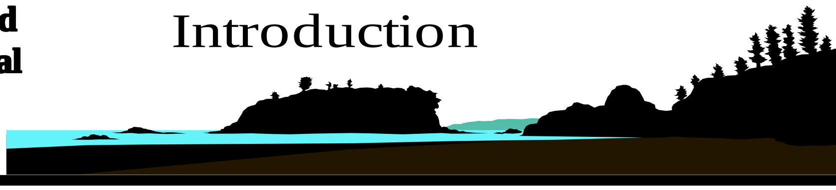
- Reptiles and amphibians were found at 94% of the sites sampled in 1994 and 1997. Salamanders were the most common group, occurring at 70 percent of the sites of the 12 species of herpetofauna collected.

SUMMARY

The major impacts to non-tidal streams in the Lower Susquehanna basin appear to be excessive nutrient enrichment and habitat degradation, particularly due to a loss of riparian habitat. Although all streams in the basin met state water quality standards, fish and benthic macroinvertebrate Indices of Biotic Integrity show evidence of biological impairment. Given the type and magnitude of the impacts noted in 1997 and the projected changes in land use, human population size, and water demands in the Lower Susquehanna basin, the biological communities and other ecological attributes of streams in the basin will likely become more degraded in years to come. Comprehensive implementation of best-management practices (BMPs), such as riparian zone protection and reforestation, may partially offset these impacts. However, it is important to note that BMPs may reduce, but do not eliminate the ecological impacts of human disturbance.

Maryland Biological Stream Survey

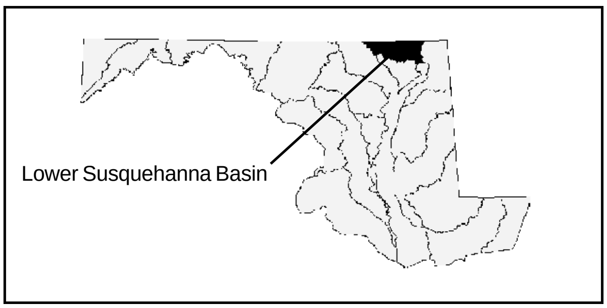
Introduction



Chapter One 1

PURPOSE OF THIS REPORT

This report describes aquatic resource conditions in first, second, and third-order non-tidal streams in the Lower Susquehanna basin in Maryland during 1997. The report also begins to identify water quality and habitat problems in the basin, along with areas of high ecological value. We hope that this information will prove useful as specific strategies for restoring water quality in Chesapeake Bay and its tributaries are developed and refined.



The Lower Susquehanna basin, one of Maryland's 18 major river basins, lies in the northeastern part of the state and includes parts of Harford and Cecil counties.

STREAM RESOURCES

The flowing waters of Maryland represent a vital lifeblood to its residents. In addition to providing a source of drinking water and water for agricultural and industrial uses, Maryland's streams and rivers offer recreational opportunities, attract tourists, and support commercially and recreationally important fish and shellfish. Forested riparian zones contain some of the richest and most diverse plant and animal communities in the state. These areas help temper the effects of heavy rainfall and storm water runoff, shade the stream channel, increase bank stability, and contribute leaf litter and woody debris--sources of food and habitat for stream biota. In many cases, the aesthetic attraction of streams and rivers has served as a catalyst for economic development. Nearly all of the flowing waters in Maryland, including those within the Lower Susquehanna basin, drain to Chesapeake Bay — therefore the quality of these systems has a direct impact on the health of the Bay. As most Marylanders know, Chesapeake Bay is one of Maryland's most important economic and natural resources.

Despite these values, Maryland's streams and rivers have been abused and neglected, often converted to flood routing systems or used as drains for unwanted wastes. Increasingly, Marylanders are realizing that our mistreatment of natural resources is neither economically nor environmentally sustainable. Efforts are underway to restore degraded systems and to protect those that are healthy. In the end, the success of these efforts will be determined by how much we cherish these most valuable natural gifts.

INFORMATION SOURCES

The primary data source for this report is the 1997 Maryland Biological Stream Survey (MBSS) conducted by Maryland Department of Natural Resources (MDNR). Where appropriate, 1994 MBSS data have been used to supplement information regarding fish and herpetofauna distributions. The MBSS is a statewide survey of first, second, and third-order streams designed to characterize current biological and habitat conditions and provide a basis for assessing future trends. The probabilistic design (all streams have a known probability of being sampled and sites are randomly selected) used for the survey allows unbiased estimates of stream characteristics and conditions. For example, the abundance of a given fish species in an entire basin can be validly estimated using the MBSS design. Because first, second, and third-order streams represent approximately 85% of the non-tidal stream miles in the Lower Susquehanna basin, MBSS results should accurately represent overall stream quality. Examination of conditions in small streams also help to identify specific problem areas where local protection, enhancement, and restoration efforts should be focused.

To provide a comparison of past and present conditions, historical information is presented where appropriate and available. In addition, information on land use, hydrology, and other aspects of the basin is also provided so that the conditions observed in streams can be placed in context of human activity.

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Maryland Biological Stream Survey

Basin Description

Chapter Two 2

This chapter uses existing information to provide an overview of the Lower Susquehanna basin, including ecological, recreational, and economic resources. This provides a context for interpreting the assessment of stream conditions found in Chapter 4. For the purposes of this report we will refer to Maryland's portion of the sub-basin as the "Lower Susquehanna" and will explicitly state when comments include Pennsylvania's portion.

HISTORY

When John Smith first explored the rivers and bays of present day Harford County in 1608, the area was inhabited by Native Americans: the Massawomeks along the Bush River, the Susquehannocks along the Susquehanna River, and the Mingoes along upper Deer Creek (Wright 1967). Fifty years later islands along the county coastline were settled by Europeans and by the turn of the eighteenth century shoreline areas began to be developed. European settlement of the inland region of the county did not occur until after Native American activity had subsided. However, colonization of the area was soon widespread and led to the establishment of the county in 1774 (Preston 1901).

In the nineteenth century, the development of railway and canal transportation facilitated the movement of both people and commodities throughout Harford County. The county railway system was completed by 1838, however access across the Susquehanna River was not established until 1866. Prior to that, train cars were ferried across the river (Wright 1967). Canal service, via the 45 mile-long Susquehanna and Tidewater Canal, was completed in 1839. The canal extended from Peach Bottom to Havre de Grace and was mainly used by boats traveling between New York, Philadelphia, and Baltimore. The canal continued operation until 1900 (Wright 1967).

Following World War II, government sponsored highway and housing projects increased development in the basin. Today, the Lower Susquehanna basin, including Pennsylvania's portion, is the most developed of the six sub-basins in the Susquehanna River drainage. Much of the basin's urban development is centered around the cities of Harrisburg, Lancaster, York, and Carlisle. Within Maryland, urbanization is a minor component, however, it is one of the most agriculturally developed areas of the state.

BASIN CHARACTERISTICS

The Susquehanna River drainage covers approximately 27,000 mi^2 in New York, Pennsylvania, and Maryland. Originating in central New York, it flows approximately 477 miles before emptying into Chesapeake Bay at Havre de Grace, Maryland. Based on the total volume of water passing at its mouth, the Susquehanna is the largest river on the eastern seaboard and the 18th largest in United States (Kammerer 1987). It is the largest tributary of Chesapeake Bay and provides about 45% of the freshwater, 40% of the sediment, 39% of the nitrogen, and 24% of the phosphorus entering the Bay on an annual basis (Risser and Siwiec 1996).

The Lower Susquehanna basin is the second largest sub-basin of the Susquehanna drainage and covers an area of 5,809 mi^2, 275 of which are in Maryland. The Maryland portion lies entirely within the Piedmont Upland Section of the Piedmont Physiographic Province, however, the upper reaches of the drainage flow through the Appalachian Plateau, Ridge and Valley, Blue Ridge, and New England provinces. The Piedmont Upland is underlain by metamorphic rocks (mainly schist, gneiss, and quartzite) and is characterized by rolling uplands with broad hills and steep-sided valleys. The 275 miles of first, second, and third-order non-tidal streams make up eighty-five percent of Lower Susquehanna basin; an additional 47 miles are fourth-order and larger streams.

Climate exerts a major influence on basin water quality, as it affects the water budget and precipitation chemistry. The quantity and chemical composition of water added through precipitation, coupled with the region's underlying geology dictate the chemical and biological features of the basin. The prevailing westerly winds and the proximity of the basin to the Atlantic Ocean provide the area with a humid continental climate. However, the lower part of the basin generally experiences more moderate temperature fluctuations and greater amounts of precipitation due to secondary circulation of warm, moist air off the Atlantic Ocean.

Mean annual precipitation throughout the basin (including Pennsylvania) ranges from 38 to 48 inches and its pH averaged between 4.08 and 4.20 during 1982-88; this is some of the most acidic precipitation in the nation (Lindsey et al. 1998). About 45 percent of the precipitation is provided through storm events from May through December. The majority of the remaining 55 percent occurs outside the growing season, thereby allowing greater infiltration and groundwater recharge.

In the 1950s and 1960s, several government agencies advocated the planting of a non-native shrub called multiflora rose as a means to enhance wildlife habitat on farms and in backyards. Since then, this species has spread into every drainage basin in the state and it continues to spread today. As a result, this introduced species now constitutes a significant threat to efforts to restore lost native vegetation along streams.

Multiflora Rose (*Rosa multiflora*)

Multiflora rose is an opportunistic plant that colonizes cleared areas such as timber cuts and pastures— often so completely that virtually no other plants can compete with it. Because aquatic insects have evolved to feed on leaves fallen from native trees and shrubs, the takeover by multiflora rose is reducing the amount of food available for them. This, in turn, has very likely led to impacts on our native fish communities which depend upon insects to survive. An additional problem is that unlike mature trees whose root systems typically extend below the water level of a stream, the roots of multiflora rose do not protect the lower stream bank where erosion is most severe. Like many other introductions, multiflora rose has resulted in unforeseen negative consequences— today, a great many riparian areas in the basin are virtually impenetrable because of the success of this noxious species.

LAND USE AND HUMAN POPULATION

Over eighty percent of the basin is comprised of agricultural and forested land (MDNR 1997a; Figures 1 and 2). Urban land use accounts for approximately 13% of the area. Open water, wetlands, and barren land collectievly make up less than 5% of the total area of the basin.

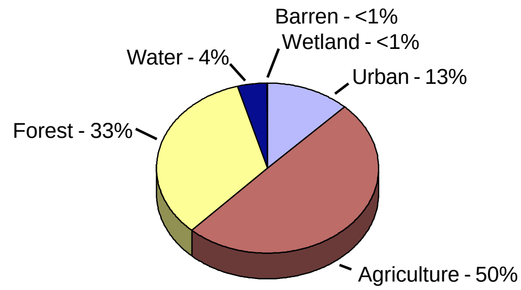


Figure 1. Land use in the Lower Susquehanna basin (MDNR 1997a).

According to 1990 census data, approximately 107,000 people live in the basin (MOP 1994). Major population centers include the towns of Aberdeen, Bel Air, Havre de Grace, and Perryville. Although not a dominant feature at present, urbanization is occuring at a moderate pace and the human population is expected to increase. By 2020 it is anticipated that the population within the basin will increase nearly thirty-nine percent to over 149,000 people.

WATER QUALITY

The Maryland Department of the Environment (MDE) classifies all surface waters in Maryland by their “designated use” (COMAR 1995). All waters of the state receive at least a Use I designation; that is, they are protected for contact recreation, fishing, and protection of aquatic life and wildlife. Use II waters are suitable for shellfish harvesting, while Uses III and IV are designated as natural and recreational trout waters, respectively. Additional designations are made for waters recognized for their function as drinking water supplies.

Within the Lower Susquehanna basin, surface waters are classified as Use I, Use III, and Use IV. There is no indication of chronic exceedance of water quality criteria and no use impairments have been noted.

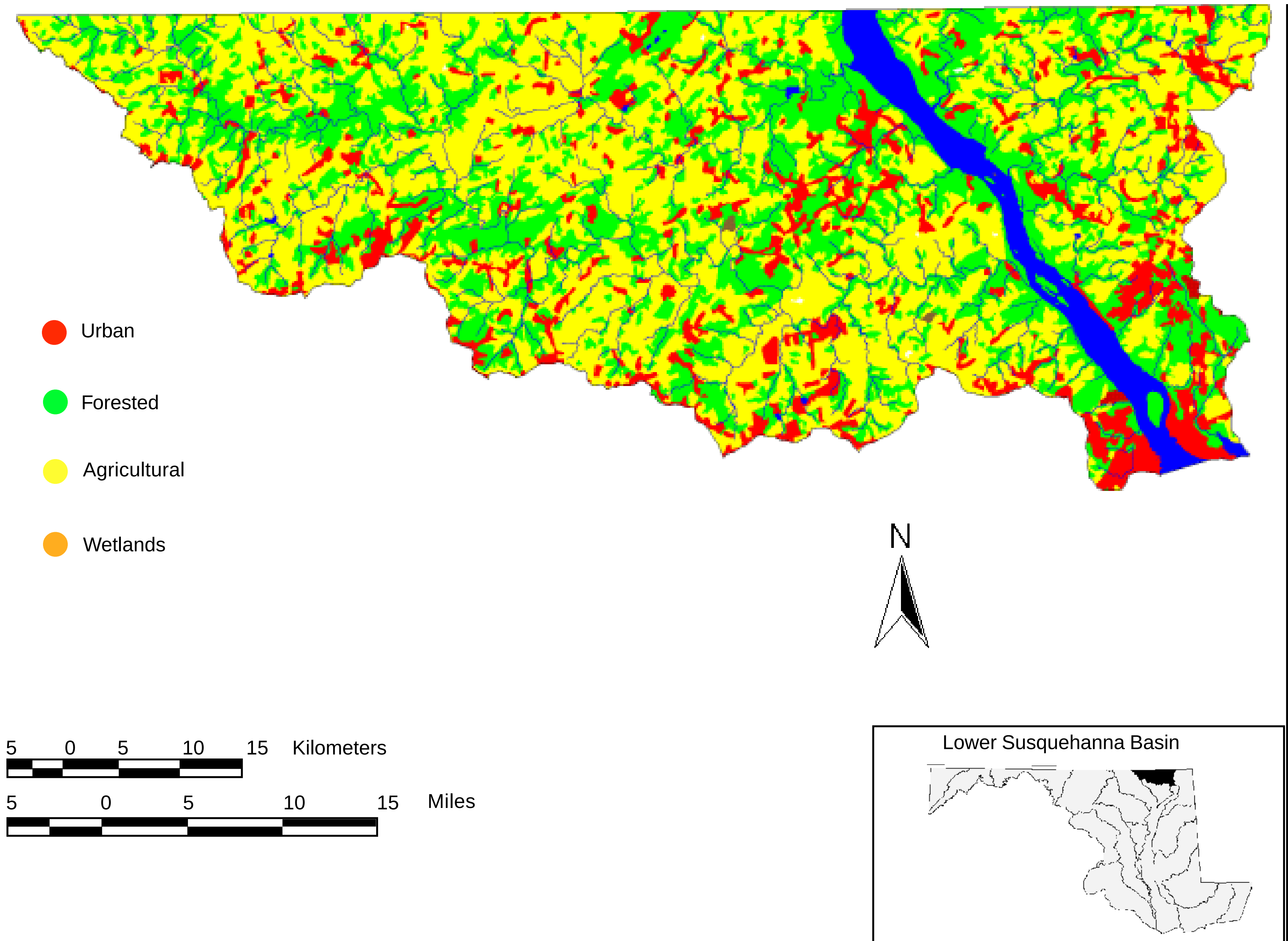


Figure 2. Land use in the Lower Susquehanna Basin (MOP 1994).

RESOURCE VALUES

Recreational Resources

The Lower Susquehanna basin offers many opportunities to participate in recreational activities. There are several state parks and Natural Resource Management areas, including: Susquehanna State Park, Rocks State Park, and Broad Creek Park. These areas offer hiking, biking, fishing, hunting, picnicking, swimming, and outdoor education.

Extractable Resources

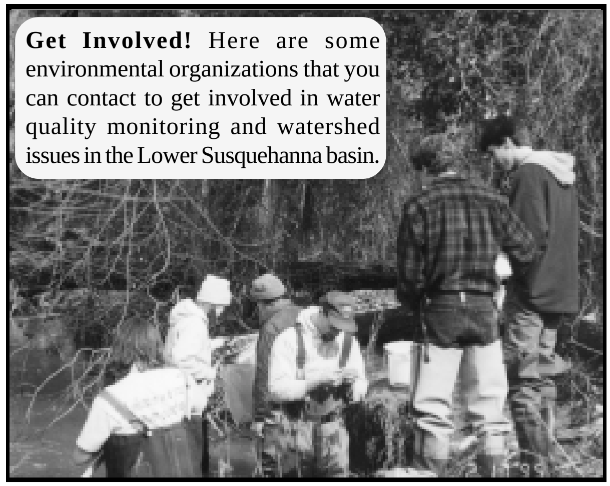
The basin contains few mineral deposits of commercial value. In addition to two crushed granite and gneiss quarries, the basin supports several sand and gravel operations (MGS 1996). These materials are used primarily in construction and local highway maintenance. Timber resources in the basin are mainly hardwoods, with tulip poplar and oak species dominating the harvest (Frieswyk and DiGiovanni 1988). Other species harvested in lesser amounts include soft maples, ashes, and black cherry.

Fishery Resources

The recreational fishery includes both freshwater and marine species. There are two designated trout streams, the Deer Creek watershed in Harford County and the Basin Run watershed in Cecil County. Deer Creek has also been designated as one of the State's Scenic Rivers and has had the lower two miles classified as "critical habitat" by the U.S. Fish and Wildlife Service for the endangered, but likely extinct, Maryland darter (MDNR 1997b). The mainstem of the Susquehanna River offers a variety of sportfishing, particularly for migratory American shad, hickory shad, and striped bass. The Lower Susquehanna boasts the nation's largest capacity fish lift operation and, following completion of the passage at the York Haven hydroelectric facility, will increase access for migratory species throughout the Susquehanna drainage.

CITIZEN INVOLVEMENT

During the last decade, an increasing number of concerned citizens have become involved in organizations working to protect and restore Maryland's aquatic resources. Many such organizations focus their work on a particular watershed and take part in monitoring activities, community outreach, and preservation issues. The following lists some of the groups that are active in the Lower Susquehanna basin.



Get Involved! Here are some environmental organizations that you can contact to get involved in water quality monitoring and watershed issues in the Lower Susquehanna basin.

Chesapeake Bay Foundation
162 Prince George Street
Annapolis, Maryland 21401

Deer Creek Scenic River
20 West Courtland Street
Bel Air, Maryland 21014

Deer Creek Watershed Association
PO Box 111
Darlington, Maryland 21034

Izaak Walton League of America
707 Conservation Lane
Gaithersburg, Maryland 20878

Save Our Streams
258 Scotts Manor Drive
Glen Burnie, Maryland 21061

Sierra Club
103 North Adams Street
Rockville, Maryland 20850

Stream Striders
1109 Spring Street
Suite 802
Silver Spring, Maryland 20910

Susquehanna River Wetlands Trust
229 Pepper Street
Muncy, Pennsylvania 17756

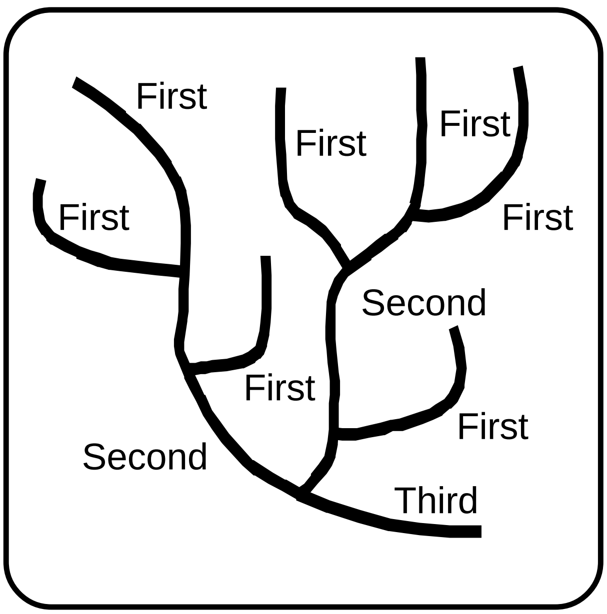
Trout Unlimited
2916 Trellis Lane
Abingdon, Maryland 21009

Maryland Biological Stream Survey

Survey Design and Methods

Chapter Three 3

This chapter briefly outlines the approach used by the MBSS assess stream resources of the Lower Susquehanna basin. The sampling design used for this assessment differs from other stream surveys that have been conducted in Maryland. Randomly selected sampling sites on first, second, and third-order non-tidal streams (Strahler 1964) were chosen by computer rather than selected by the investigator. This approach allows estimates to be calculated for an array of ecological factors such as fish density and stream habitat condition. Non-randomly selected sites were also sampled to provide additional information on fish distributions. Figure 3 shows the location of random and non-random sites sampled during the 1994 and 1997 MBSS.



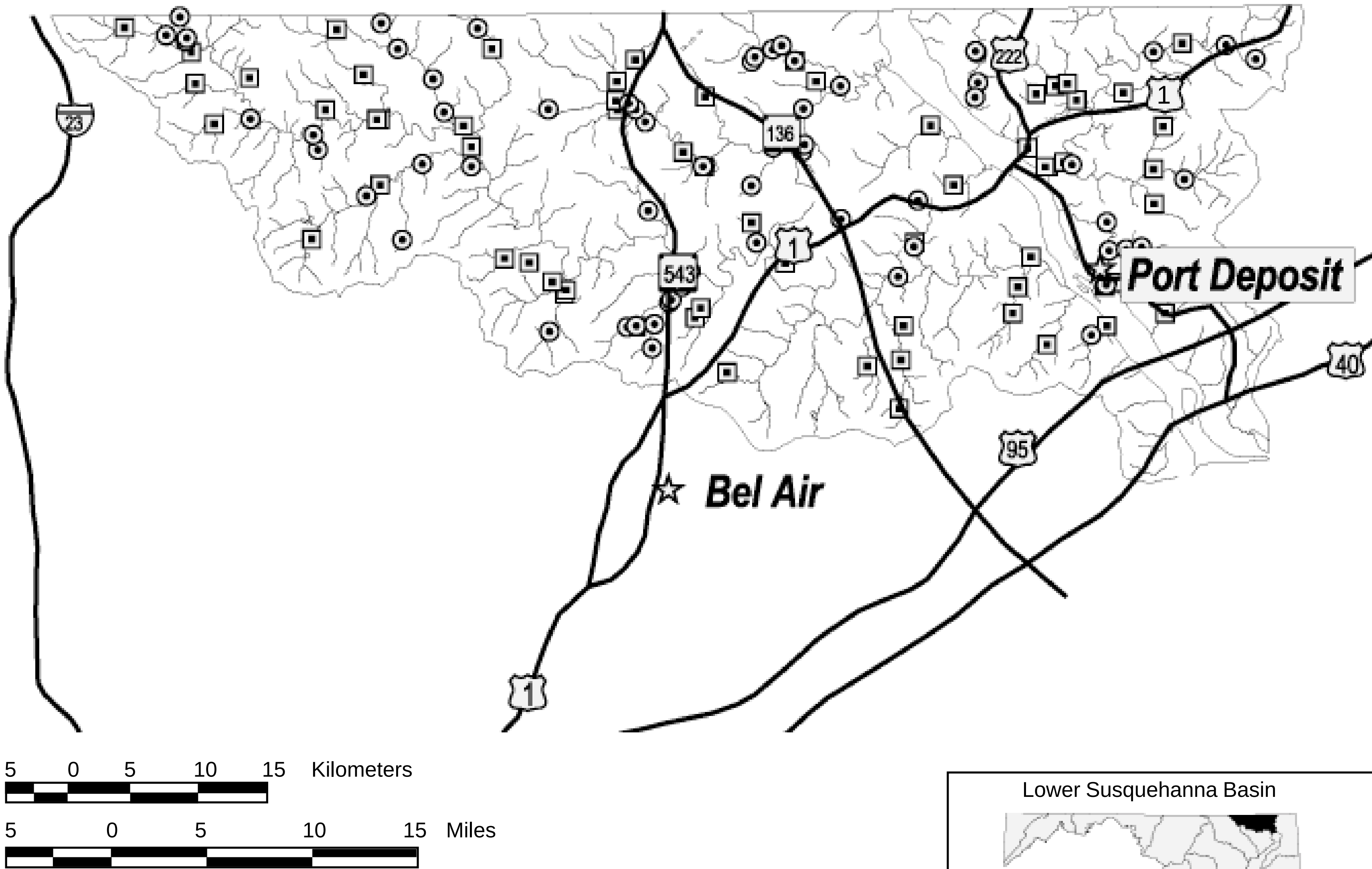
STREAM ORDER

Stream order is a simple way to measure stream size. The smallest permanently flowing stream is termed first-order, and the union of two first-order streams creates a second-order stream. A third order stream is formed where two-second order streams join. Stream order is directly related to watershed area.

After landowner permissions were obtained, sample sites were located with Global Positioning System (GPS) receivers, fish and benthic macroinvertebrates were collected, and physical habitat features were evaluated using methods patterned after EPA's Rapid Bioassessment Protocols (Plafkin et al. 1989). Reptiles, amphibians, and mussels were also surveyed on a presence/absence basis. Water quality was sampled using protocols previously established for acid rain studies in Maryland (MDNR 1988). Because the initial purpose of the MBSS was to assess the effect of acid rain on Maryland streams and rivers, other important water quality measures such as phosphorous and turbidity were not measured.

Because most stream sites in the Lower Susquehanna basin were on private land, landowner permissions were sought for each randomly selected site. This procedure required contact with property owners, usually by phone. Overall, 97% of the landowners contacted in the basin gave DNR permission to have streams on their property sampled by the MBSS.

All catchments draining to the MBSS sampling sites were delineated and land use (MOP 1994) was estimated for each. Throughout all sampling and data management activities, an extensive Quality Control program was employed. Additional technical information about the methods used to survey streams and survey results can be found in Appendices A through D of this report, in Roth et al. (1999), and in Kazyak (1996).



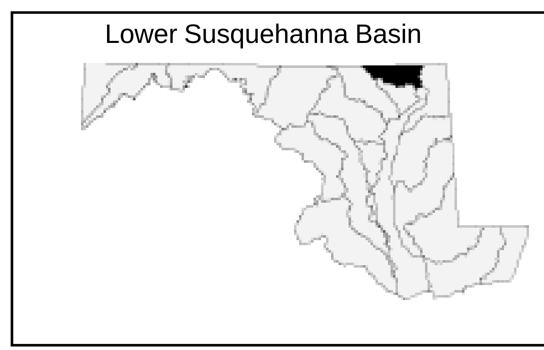


Figure 3. Location of 1994 and 1997 sites in the Lower Susquehanna basin. Major highways, population centers, and other features are shown for reference.

Chapter Four 4

This chapter uses 1997 MBSS data from 35 randomly selected (quantitative) sites to describe the current status of non-tidal streams in the Lower Susquehanna basin. Where appropriate, 1994 and 1997 data have been used from random and non-random (qualitative) sites to supplement information regarding fish and herpetofauna distributions. A map of these sites is shown in Figure 3 and a list of the streams sampled is presented as Appendix B.

GENERAL CHARACTERISTICS OF THE LOWER SUSQUEHANNA BASIN

All of the Lower Susquehanna basin sampling sites were within the Piedmont physiographic province. Piedmont streams tend to be of moderate gradient and contain large substrate. The combination of these two factors helps create riffles which serve to aerate the water and, in turn, replenish dissolved oxygen lost through nutrient over-enrichment and high biological oxygen demand. Conversely, Coastal Plain streams are lower gradient systems and are often dominated by smaller substrate, such as sand. As a result, Coastal Plain streams are generally less biologically productive. The "fall line", which closely follows Interstate 95, separates these two physiographic provinces. In the Lower Susquehanna basin, this line lies just upstream of the mouth of the Susquehanna River.

Of the thirty-five sites sampled in 1997, first and second-order streams were each represented by 12 sites and third-order streams were sampled at 11 sites. The sites represented a broad range of stream sizes, from less than 1 meter wide to approximately 23 meters.

WATER QUALITY

During the spring index period, whole water grab samples were collected at each site for laboratory analysis of pH, acid neutralizing capacity (ANC), conductivity, sulfate, nitrate-nitrogen, and dissolved organic carbon (DOC). Summer index period sampling included *in situ* measurements of dissolved oxygen (DO), pH, temperature, and conductivity at each site to further characterize water quality conditions. Water chemistry data from the 1997 quantitative sites are presented in Appendix C.

> Dissolved oxygen (DO) is one of the most basic requirements of aquatic organisms, thus DO levels play an important role in shaping biological communities in streams. DO in streams may be low due to nutrient-rich runoff and groundwater inputs from urban and agricultural areas, oxygen demanding organic chemicals in point source discharges, or the breakdown of naturally-occurring organic material such as leaves. The State of Maryland has established a minimum surface water criterion of 5 milligrams per liter (mg/L, also known as parts per million) for DO. When DO is low (i.e., less than 5 mg/L), only those organisms adapted to low DO can persist. In the Piedmont Plateau, streams typically have riffles, where water bubbles over rocks. Riffles help to keep DO levels high by aerating the water. In heavily impacted streams, DO may drop severely during the early morning hours because oxygen production from plants ceases at night while oxygen consumption by both plants and animals continues. During MBSS summer sampling, dissolved oxygen is measured only once during the day.

Dissolved Oxygen

No stream miles in the basin had dissolved oxygen levels below the state water quality criterion of 5.0 mg/L (COMAR 1997). Values ranged from a low of 5.4 mg/L (at only one site) to 11.1 mg/L, suggesting that runoff of oxygen demanding materials in the basin does not result in widespread DO problems. However, it should be noted that these data only reflect first through third-order systems and do not take into account larger tributaries where DO problems are common. The same runoff that enters these streams ultimately reaches Chesapeake Bay and the cumulative effects can contribute to water quality problems there.

pH and Acid Neutralizing Capacity

Significant adverse impacts on aquatic life are known to occur when pH values fall to 5.0, and below 4.5 faunal exclusion occurs (Allan 1995, Jefferies and Mills 1990). Exposure to low pH conditions can be chronic or acute, but both may result in increased mortality and/or decreased reproductive success of fish and benthic macroinvertebrates.

In 1997, no stream miles in the basin fell below a pH of 5.0. Sampling sites had an average pH of 7.2 and

Acidity is an important aspect of stream health. The balance between free hydrogen ions (which increase acidity) and negative ions (which decrease acidity) is measured as pH. The capacity of soil or water to absorb acids without changing the ion balance is known as its buffering capacity, measured as alkalinity or Acid Neutralizing Capacity (ANC). Streams with ANC less than 0 µeq/L are acidic and have no buffering capacity. Streams with baseflow ANC between 0 and 200 µeq/L are only moderately buffered and may periodically have low pH levels during rain or snowmelt events. Those streams with ANC greater than 200 µeq/L are well-buffered. Under acidic conditions, certain metals such as aluminum are dissolved into water and reach levels that can be lethal to aquatic organisms. Acidity in streams is affected by rain, snow, fog, and atmospheric dust, geology and soil characteristics, and organic matter.

Acidification of streams can be either chronic or episodic, depending on the capacity of the stream to buffer acid inputs. Chronically acidified streams generally contain only those organisms highly tolerant of acid conditions. In contrast, streams which are only episodically acidified can and often do support less tolerant "invaders" from better buffered downstream areas during summer low flow periods.

approximately 94% of the stream miles had values greater than 6.0. These values represent a one-time measure and provide an indication of chronic acidification. This, however, does not exclude the possibility of acute events. Similarly, no stream miles had acid neutralizing capacity values less than 0 μeq/L, supporting the pH findings that chronic acidification is not a problem. In fact, all of the Lower Susquehanna basin streams are well-buffered with ANC values above 200 μeq/L.

Nitrates and Dissolved Organic Carbon

Ninety-four percent of the basin's stream miles had nitrate concentrations greater than 1mg/L, suggesting that excess nutrients are a widespread environmental problem (Figure 4). The single grab samples collected during spring baseflow conditions represent relative nitrate contributions from groundwater inputs. Although these data do not account for seasonal or temporal variability, they do provide an effective method for identifying watersheds with elevated nutrient levels, particularly from groundwater sources. Because of the high groundwater concentrations, a reduction in point and non-point sources of nitrates to surface waters will only be recognized after groundwater sources are purged of their supplies.

Two important indicators of the sources of acidity in Maryland streams are nitrate and dissolved organic carbon (DOC).

One important source of nitrates in Maryland streams is deposition from the atmosphere. However, leaching into groundwater and direct runoff of fertilizers and animal wastes used on agricultural lands, discharges from sewage treatment plants, and leaking of septic systems are more important sources of nitrates to streams. Stream nitrate concentrations greater than 1 mg/L are elevated compared to undisturbed streams (Morgan 1995).

The primary source of DOC in streams is leachate from decaying leaves and other plant material that are natural sources of organic matter found within the stream drainage network itself, especially wetlands. DOC concentrations greater than 10 mg/L indicate that organic acids contribute significantly to overall acidity, but DOC levels between 5 and 10 mg/L also indicate that natural sources are contributing to overall acidity in a stream (Morgan 1995).

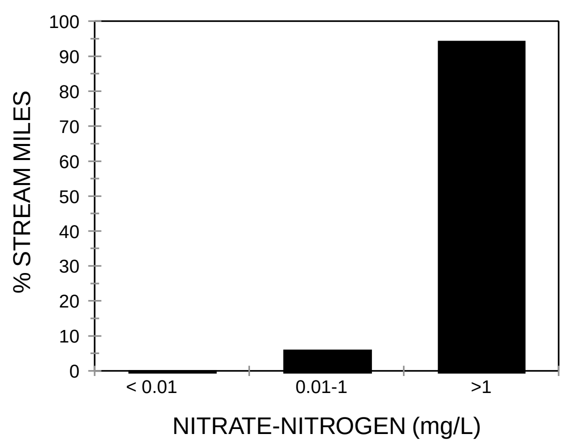


Figure 4. Nitrate-nitrogen concentration in non-tidal streams of the Lower Susquehanna basin (1997).

Approximately eighty-seven percent of stream miles had dissolved organic carbon (DOC) levels less than 5mg/L; the remaining 13 percent had concentrations between 5 and 10 mg/L. This indicates that natural sources of acidity are not a significant influence on stream water quality in the basin (Figure 5). With the exception of three sampling sites, Stone Run and unknown tributaries to Stone Run and the Susquehanna River, DOC levels were below 5 mg/L.

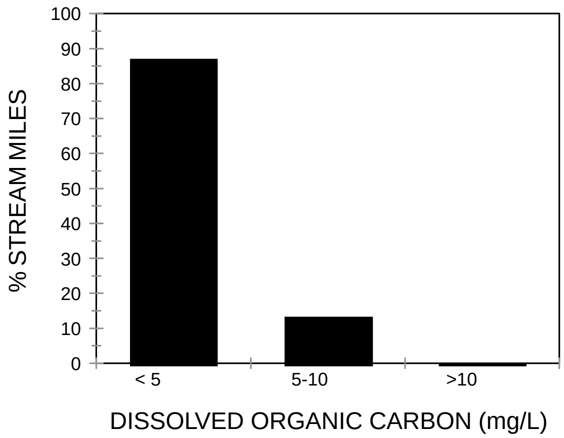


Figure 5. Dissolved organic carbon (DOC) in non-tidal streams of the Lower Susquehanna basin (1997).

PHYSICAL HABITAT

Many physical habitat characteristics of streams are important determinants of ecosystem structure and function. Although a large number of habitat variables are measured by the MBSS, they can be grouped into four general categories: instream habitat, channel character, riparian zone, and aesthetics/remoteness. Most variables are classified as Good, Fair, Poor, or Very Poor. A description of selected MBSS physical habitat variables is included in Appendix D.

Instream Habitat

> **What is habitat?**
> The physical/chemical theater in which the ecological play takes place; it is a template for the biota, their interactions, and their evolution (ITFM 1995).

The complexity and stability of habitat in a stream typically has the strongest relationship to abundance and diversity of the biological communities that occur there. Important instream habitat characteristics include: 1) quality, composition, and heterogeneity of the stream bottom; 2) diversity of depth and flow; and 3) amount and quality of stable habitat for fish shelter and attachment sites for benthic macroinvertebrates.

Many instream habitat problems result from the removal or loss of woody debris from stream channels in agricultural or urban areas; little to no buffer between pastures, croplands, urban lands and streams; increases in sediment loads; and modification of stream channels because of increased runoff. These impacts are common when lands are developed for agricultural or urban uses. Within the Lower Susquehanna, nearly ninety-five percent of the stream miles were rated Good or Fair for instream habitat; no streams rated Very Poor (Figure 6).

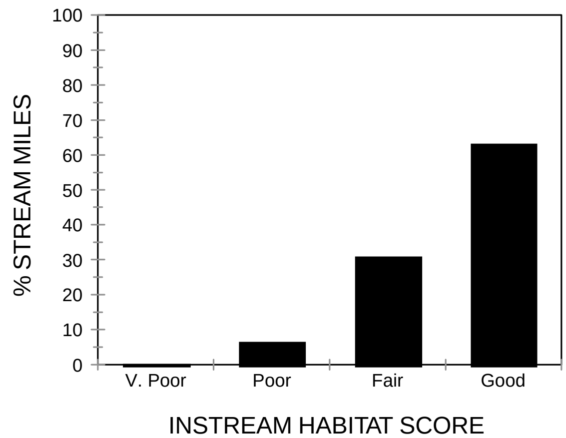


Figure 6. Instream habitat scores for non-tidal streams of the Lower Susquehanna basin (1997).

Suspended sediment tends to reduce the complexity and stability of the stream bottom, resulting in a loss of habitat for fish and benthic macroinvertebrates. Another common outcome is the coating or burial of stones by silt and sand in riffle areas. The percent embeddedness of substrate in riffles provides an indication of the amount of sediment moving downstream and the availability of interstitial spaces for stream biota. In the Lower Susquehanna, over ninety percent of first through third-order stream miles had favorable embeddedness ratings (Figure 7).

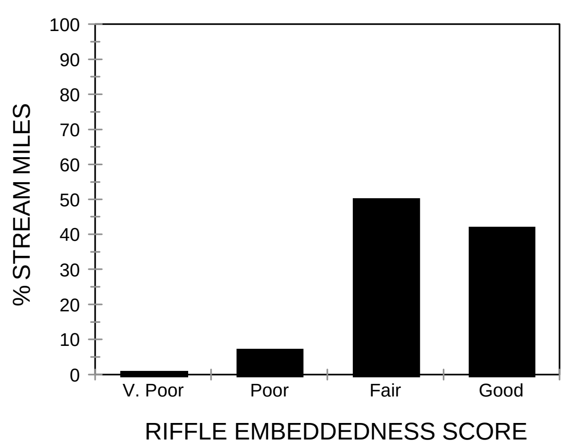


Figure 7. Riffle embeddedness for non-tidal streams of the Lower Susquehanna basin (1997).

Another impact to instream habitat quality is a reduction in the abundance of wood (i.e. logs, limbs, and rootwads) along stream banks and in stream channels compared to historical levels. Wood in streams may greatly enhance habitat quality for both fish and benthic macroinvertebrates by providing a diverse array of shelter, depths, and velocities. Woody debris also traps and retains leaves, a vital food supply for many benthic macroinvertebrates. By retaining organic mater in and near the stream channel, the export of nutrients to Chesapeake Bay is reduced. A lack of woody debris and rootwads was clearly evident within the basin. There were an estimated 70 pieces of woody material per stream mile in the Lower Susquehanna, well below the statewide average of 91 pieces per mile. In addition, approximately twenty-one percent of all stream miles lacked any woody material. As a measure of comparison, wood often controls 80% or more of the channel in streams within old growth forests (Maser and Sedell 1994); thus woody debris densities in the Lower Susquehanna basin prior to extensive human disturbance were likely much higher than the most pristine stream sampled in 1997.

In addition to the effects still felt from the original clear cutting of the basin, a continuing cause of the reduced abundance of woody debris and rootwads is related to prevailing forestry practices. In today's managed forests, trees are rarely allowed to achieve senescence; thus one of the vital and controlling elements of instream habitat (large dead trees and tree limbs) is largely prevented from falling into streams. In addition, woody debris that falls into streams during logging is routinely removed.

Channel Characteristics

Large-scale disturbances in the stream channel may result from watershed development or channel modification. Evidence of stream channel disturbance includes excessive bar formation, the presence of artificial structures (e.g., concrete armoring and rip-rap), reduced stream flows because of water removal for irrigation and other uses, and severe bank erosion. Approximately 7% of first through third-order stream miles in the basin are artificially straightened or channelized in some way. During channelization, trees in the riparian zone are often cut and woody debris is removed from the stream channel to allow for efficient movement of water away from agricultural fields or housing developments. As a result, heavily channelized streams are generally shallow, with little habitat for living resources, while downstream areas suffer from increased flooding problems. Channelization also causes reduced retention and rapid transport of nutrients into Chesapeake Bay.

As lands within the basin were developed for agriculture and then urbanized, many miles of stream banks were destabilized and sand/silt bars formed in slow moving areas. Currently, only 8% of all stream miles in the basin have degraded channel conditions (Figure 8). However, an additional twenty-six percent are in Poor condition and, if existing land use trends persist, will likely continue to deteriorate. Although sixty-five percent of the stream miles have relatively stable banks, some of these are concrete trapezoids which increase erosion in downstream areas by constricting flow and increasing current velocites. The instability of the stream channels limits the availabilty of instream habitat through sedimentation and ultimately increases nutrient and sediment transport to Chesapeake Bay.

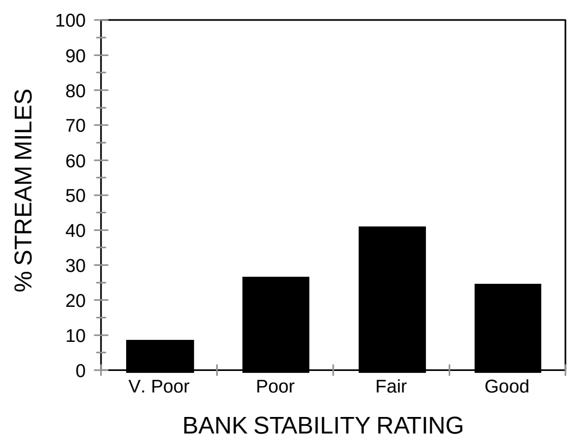


Figure 8. Bank stability rating for non-tidal streams of the Lower Susquehanna basin (1997).

Riparian Zone

Forest cover along streams decreases exposure of the channel to direct sunlight and helps prevent warming of stream waters above their natural range. Conditions of the riparian zone along the Lower Susquehanna basin in 1997 were fair (Figure 9). Forested buffers accounted for approximately 51% of the basin's riparian zone and about 30% of the stream miles had

Riparian zones are the areas along side streams, rivers, and other waterbodies. When these areas are vegetated, they play a vital role in structuring and maintaining physical habitat, energy flow, and aquatic community composition. Vegetated (trees, shrubs, and grasses) riparian zones act as buffers by decreasing runoff and preventing particulate pollutants from entering streams (Plafkin et al. 1989). Trees and shrubs also provide energy inputs to the stream in the form of leaf litter and woody debris, stabilize stream channels, supply overhead and instream cover for fishes and other aquatic life, and moderate stream water temperature.

forested riparian zones greater than 50 meters wide. However, nearly one-quarter of the stream miles had unvegetated riparian zones and thus were not well protected against runoff. Other vegetation types, such as old field, mowed lawn, and tall grass were common.

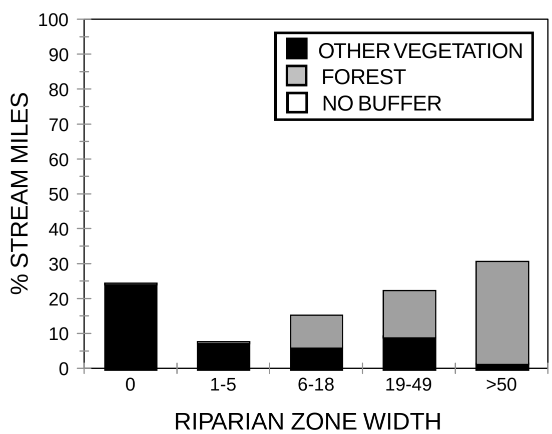


Figure 9. Riparian zone width and type in Lower Susquehanna basin streams (1997). Other vegetation includes old field, mowed lawn, and tall grass.

Aesthetics/Remoteness

The aesthetic and remoteness ratings provide a qualitative estimate of the level of anthropogenic influence on a stream system and, in turn, may indicate stress on the biological community. Within the Lower Susquehanna these parameters were somewhat contradictory. The aesthetic rating indicated degraded conditions in less than thirty percent of the stream miles, with no miles within the Very Poor category (Figure 10). Remoteness ratings were less favorable with nearly 60% of the stream miles lying within one-quarter mile of a roadside. Of this, 35 percent were immediately adjacent to a road.

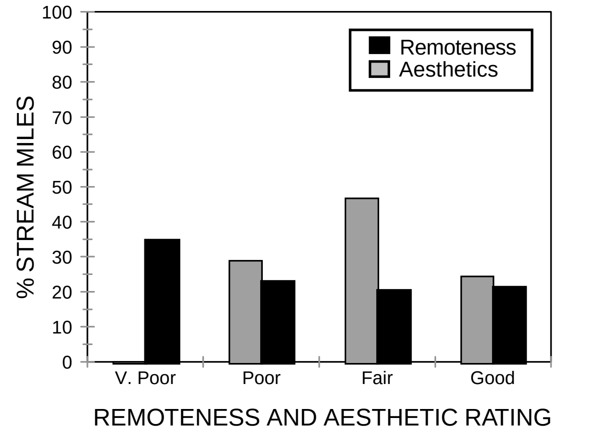


Figure 10. Remoteness and aesthetic ratings for non-tidal streams of the Lower Susquehanna basin (1997).

HABITAT QUALITY BASED ON PHYSICAL HABITAT INDEX (PHI)

In addition to evaluating habitat components individually, the MBSS has developed an index which combines those aspects of physical habitat which have proven to be the best indicators of biological condition (Hall et al. 1999). Based on this index, more than one-quarter (26%) of the stream miles in the basin have Poor or Very Poor physical habitat, and only 20% have Good habitat (Figure 11).

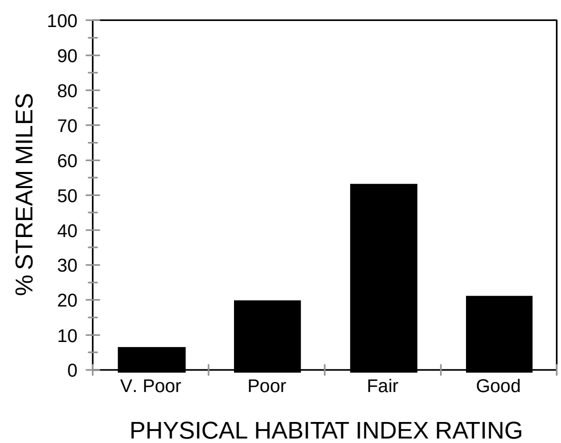


Figure 11. Physical Habitat Index (PHI) rating for non-tidal streams of the Lower Susquehanna basin (1997).

FISHERY RESOURCES

General Description

A total of 47 fish species representing 12 families were collected in the Lower Susquehanna basin in first through third-order in streams during 1994 and 1997. Based on 1997 MBSS sampling, total abundance was

Table 1. Estimated total abundance and percentage occurence of fish species collected in the Lower Susquehanna basin in 1997 (first, second, and third-order combined) and a comparison of fish species taken at random versus non-random sites.

Family / Common Name	(Scientific Name)	Percentage Occurrence[1]	Population Estimate[2,3]	Standard Error
Petromyzontidae				
Sea Lamprey	(*Petromyzon marinus*)	9.5	30,600	24,367
Anguillidae				
American Eel	(*Anguilla rostrata*)	67.9	114,623	19,505
Clupeidae				
Gizzard Shad	(*Dorosoma cepedianum)*	0.7	*	*
Cyprinidae				
Blacknose Dace	(*Rhinichthys atratulus*)	93.4	987,171	130,390
Bluntnose Minnow	(*Pimephales notatus*)	11.7	64,140	37,210
Central Stoneroller	(*Campostoma anomalum*)	14.6	71,949	28,827
Common Carp	(*Cyprinus carpio*)	5.1	617	540
Common Shiner	(*Luxilus cornutus*)	37.2	106,326	28,676
Creek Chub	(*Semotilus atromaculatus*)	83.2	458,572	126,854
Cutlips Minnow	(*Exoglossum maxillingua*)	57.7	84,381	11,496
Fallfish	(*Semotilus corporalis*)	40.1	49,300	13,896
Golden Shiner	(*Notemigonus crysoleucas*)	3.6	172	100
Longnose Dace	(*Rhinichthys cataractae*)	54.0	129,746	31,933
River Chub	(*Nocomis micropogon*)	27.7	25,741	5,494
Rosyface Shiner	(*Notropis rubellus*)	5.8	1,561	2,723
Rosyside Dace	(*Clinostomus funduloides*)	78.8	508,588	197,849
Satinfin Shiner	(*Cyprinella analostana*)	14.6	13,611	5,012
Spotfin Shiner	(*Cyprinella spiloptera*)	2.9	2,467	2,733
Spottail Shiner	(*Notropis hudsonius*)	11.7	30,637	16,297
Swallowtail Shiner	(*Notropis procne*)	18.2	13,307	37,689
Catostomidae				
Creek Chubsucker	(*Erimyzon oblongus*)	2.9	*	*
Northern Hogsucker	(*Hypentelium nigricans*)	37.2	19,411	3,242
Shorthead Redhorse	(*Moxostoma macrolepidotum*)	1.5	*	*
White Sucker	(*Catostomus commersoni*)	72.3	235,811	86,332
Ictaluridae				
Brown Bullhead	(*Ameiurus nebulosus*)	4.4	819	716
Channel Catfish	(*Ictalurus punctatus*)	1.5	*	*
Margined Madtom	(*Noturus insignis*)	40.9	61,343	58,777
Yellow Bullhead	(*Ameiurus natalis*)	3.6	2,317	1,699
Salmonidae				
Brook Trout	(*Salvelinus fontinalis*)	7.3	44,461	29,684
Brown Trout	(*Salmo trutta*)	23.4	22,810	14,390
Rainbow Trout	(*Oncorhynchus mykiss*)	2.2	*	*
Fundulidae				
Banded Killifish	(*Fundulus diaphanus*)	1.5	96	90
Mummichog	(*Fundulus heteroclitus*)	0.7	*	*
Cottidae				
Mottled Sculpin	(*Cottus bairdi*)	21.9	293,093	122,673
Moronidae				
White Perch	(*Morone americana*)	1.5	*	*
Centrarchidae				
Bluegill	(*Lepomis macrochirus*)	25.5	22,165	18,073
Green Sunfish	(*Lepomis cyanellus*)	16.8	6,709	2,440
Largemouth Bass	(*Micropterus salmoides*)	8.0	5,000	3,986
Smallmouth Bass	(*Micropterus dolomieu*)	24.8	4,867	2,180
Pumpkinseed	(*Lepomis gibbosus*)	16.8	10,020	7,629
Redbreast Sunfish	(*Lepomis auritus*)	21.2	15,422	10,090
Rock Bass	(*Ambloplites rupestris*)	9.5	1,425	1,284
Percidae				
Banded Darter	(*Etheostoma zonale*)	1.5	*	*
Logperch	(*Percina caprodes)*	2.2	9,367	8,938
Shield Darter	(*Percina peltata*)	9.5	1,548	650
Tessellated Darter	(*Etheostoma olmstedi*)	72.3	220,068	59,275
Yellow Perch	(*Perca flavescens*)	2.2	*	*

1 Percent of all random and non-random sites where each species was collected, including 1994 sites.
2 Total abundance (number per basin) adjusted for capture efficiency (Heimbuch et al. 1997).
3 Non-random site information was not used in calculating population estimates.

approximately 3.5 million fish. Basin-wide population estimates for individual species ranged from less than 100 individuals for banded killifish to approximately 1 million for blacknose dace (Table 1). Consistent with the presence of predominately warm water habitat, the minnow family (Cyprinidae) was represented by the greatest number of species (17), followed by seven species of sunfish (Centrarchidae). The remaining families were comprised of five or fewer species.

The five most abundant fishes, blacknose dace, rosyside dace, creek chub, mottled sculpin, and white sucker, accounted for about 62 percent of the fish in the basin (Figure 12).

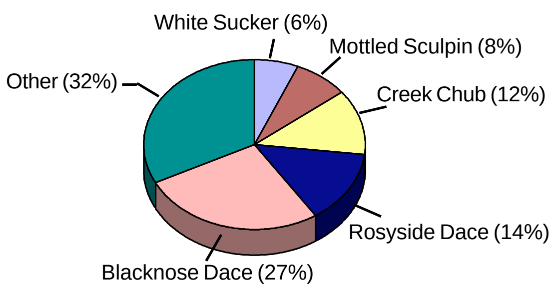


Figure 12. Relative abundance of the five most common fish species in non-tidal streams of the Lower Susquehanna basin (1997).

Five species of gamefish were collected, three of which were found in the second highest densities in the state. Brook trout, brown trout, and smallmouth bass were only found in higher densities in the Youghiogheny, Gunpowder, and Elk basins, respectively. Largemouth bass were present in small numbers, and rainbow trout were collected only at qualitative sites. Brook trout were by far the most abundant gamefish with nearly twice the density of brown trout (Table 1). Brook and brown trout were the only legal size gamefish captured, comprising 10% and 20% of the total catch of each species, respectively. Other species which provide angling opportunities, such as white perch, yellow perch, channel catfish, and bullheads, were also captured in relatively small numbers.

Rare and Uncommon Species

Of the fish species collected, only logperch are considered uncommon. Logperch have been designated as “S1” or “Highly State Rare” in the Maryland Wildlife and Heritage Program’s ranking of flora and fauna (MDNR 1997). In the Lower Susquehanna basin logperch occurred at only 2 percent of the sites with an estimated population of about 9,000 individuals or 34 fish per stream mile (Table 1).

Introduced Species

Exotic introductions generally have an adverse impact on native biota or natural habitats. Carp, brown trout, and rainbow trout were introduced to Maryland in the late 1800s and presently maintain naturalized populations in the Lower Susquehanna basin, as well as statewide. With the exception of carp, these introductions have generally been favorably viewed by the public because of the angling opportunities they present. Other, more “local” introductions have been less conspicuous because of their origin or lack of sportfishing value. These include: large and smallmouth bass, channel catfish, rock bass, bluegill, green sunfish, banded killifish, and banded darter. These species, native to the Youghiogheny drainage, have become established in basins around the state and to a large extent their impact on resident fishes is unknown.

Migratory Species

> There are three types of migratory fish in Maryland, anadromous, semi-anadromous, and catadromous. Anadromous species live as adults in estuarine or marine waters, moving into freshwater to spawn. Semi-anadromous species live as adults in estuarine or riverine waters, also moving into freshwater to spawn. However, semi-anadromous species migrate lesser distances. Conversely, catadromous American eels grow to adulthood in freshwater, migrating to marine waters to spawn.

American eel, sea lamprey, and white perch were the only migratory species collected in the Lower Susquehanna basin in 1994 and 1997. Abundance and density estimates of American eel were among the highest in the state with an estimated population of 114,000 or about 417 per stream mile. Similarly, sea lamprey were the most abundant in the state with approximately 31,000 individuals (111 per stream mile). White perch were only captured at qualitative (non-random) sites. However, because MBSS fish sampling was conducted from June through September, well after the spawning period of anadromous and semi-anadromous fish, few adults would be expected in the streams sampled.

One factor that limits the number of migratory fish within a basin is the presence of migration barriers (e.g., dams and culverts). The Lower Susquehanna basin contains 52 known barriers, and most of the stream miles are upstream from at least one migration barrier (MDNR 1999). Conowingo Dam, located approximately 10 miles upstream of the mouth of the Susquehanna River, remains a substantial barrier to fish migration despite having one of the most successful and largest fish passage facilities in the nation. However, passage operations are directed toward commercially important species such as striped bass and American shad and remain impassable to many other fish species. An exception is the American eel which has a unique ability to leave the water and move around barriers. Although American eels can circumvent most obstacles that are impassable to other migratory fish, the majority of these fish are forced to use habitat downstream of the lowest barrier in the basin and are prevented from moving upstream into smaller streams.

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates, or more simply "benthos", are animals without backbones that are larger than 0.5 millimeters (the size of a pencil dot). These animals live on rocks, logs, sediment, debris, and aquatic plants during some stage of their lives. The benthos include crustaceans, such as crayfish; mollusks, such as clams and snails; aquatic worms; and immature forms of aquatic insects, such as stonefly and mayfly nymphs.

Of the approximately 350 genera of stream-dwelling macroinvertebrates in Maryland, 111 were found in the Lower Susquehanna basin. The total number of taxa per site ranged from 8 to 29 . Dominant taxa and their respective percent occurrence (among all sites in the basin) were: *Ephemerella* (a burrowing mayfly; 86%), *Cricotopus/Orthocladius* (non-biting midges; 78%), *Prosimulium* (a blackfly;76%), *Cheumatopsyche* and *Hydropsyche* (both filter-feeding caddisflies; 73%) and *Stenonema* (a mayfly; 68%). A complete list of all benthic taxa collected in the basin and their associated feeding groups and tolerance classifications is presented in Appendix F.

Stream Quality Based on an Index of Biotic Integrity (IBI)

DNR recently developed an Index of Biotic Integrity (IBI) for non-tidal stream fish communities (Roth et al.1997) that is an effective tool for evaluating ecological conditions in streams. Using this IBI, various characteristics of the fish community are compared to results from high quality reference streams and scored. The summary score is then used to assess ecological conditions of streams in the basin as Good, Fair, Poor, or Very Poor.

The results of the fish and benthic macroinvertebrate IBIs indicate some biological impairment throughout the Lower Susquehanna basin (Figures 13 - 15).

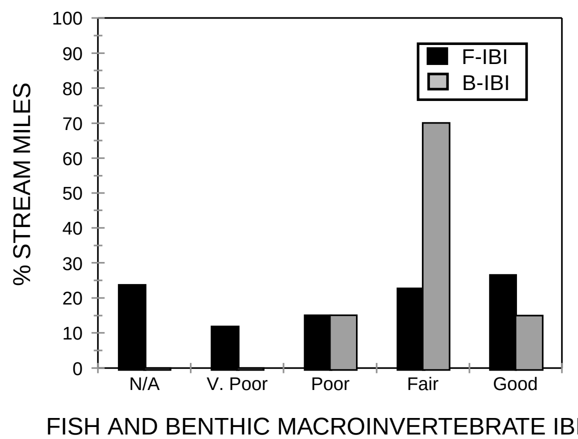
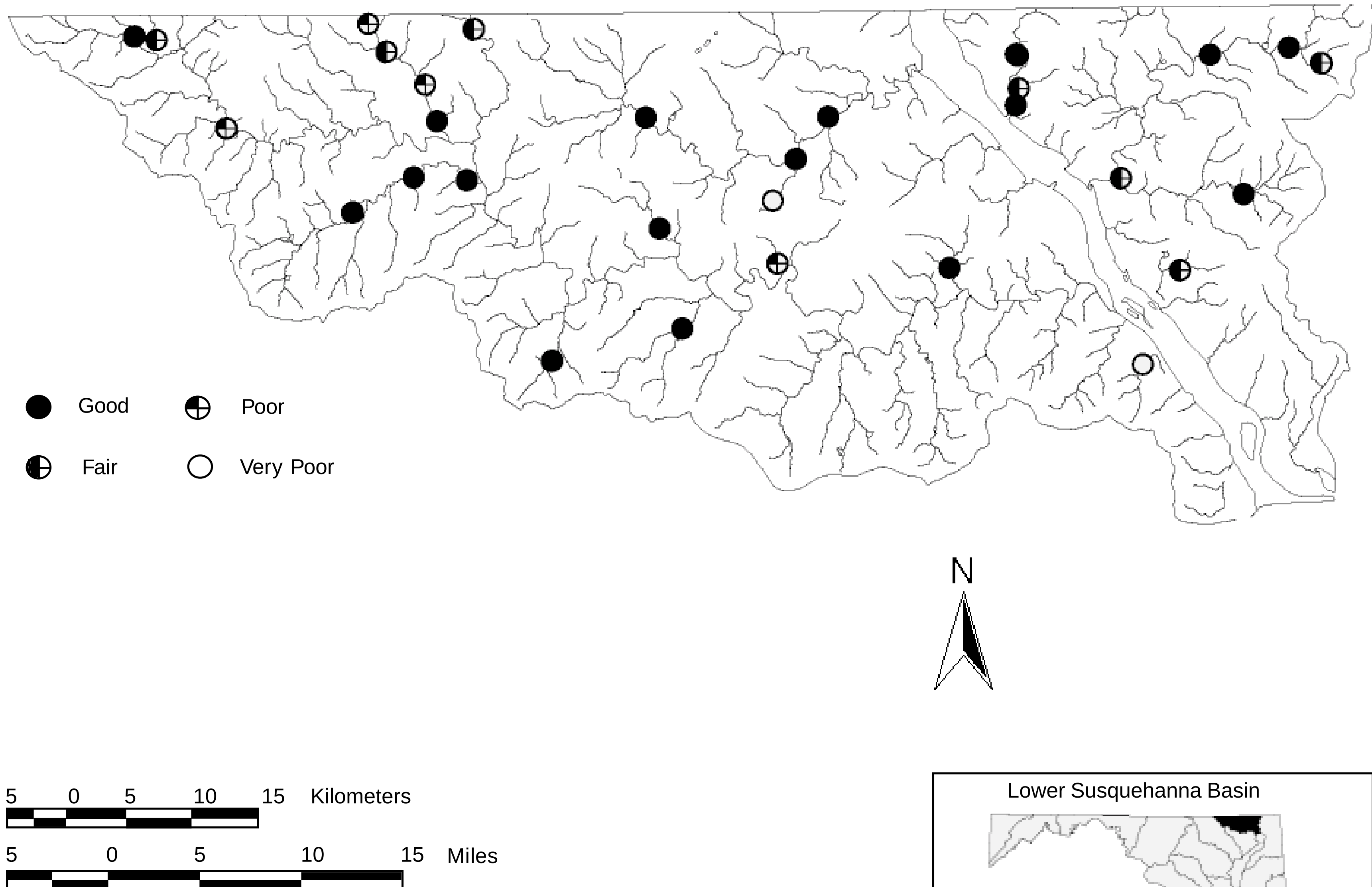


Figure 13. Fish (F-IBI) and benthic macroinvertebrate (B-IBI) Index of Biotic Integrity scores for non-tidal streams of the Lower Susquehanna basin (1997).
*N/A (Not Assessed) - sub-watershed <300 acres

Nearly fifty percent of the streams miles were rated "Fair" or better using the fish IBI. Similarly, eighty-five percent were rated "Fair" or better when assessed with the benthic macroinvertebrate IBI. However, over twenty percent of the streams were rated Poor or Very Poor by the fish IBI and the majority of sites within the Fair rating of both IBIs fell within the lower range of that category. This suggests that although current biological impairment is not prevalent, the potential exists for widespread biotic degradation. Approximately twenty-five percent of the stream miles were not eligible for the fish IBI because of the watershed size criterion of the index. Because of the inherent physical limitations of streams in small watersheds (i.e., small channel dimensions and lack of stable water flow) and the effect on fish community dynamics, sites with less than a 300 acre watershed were excluded from



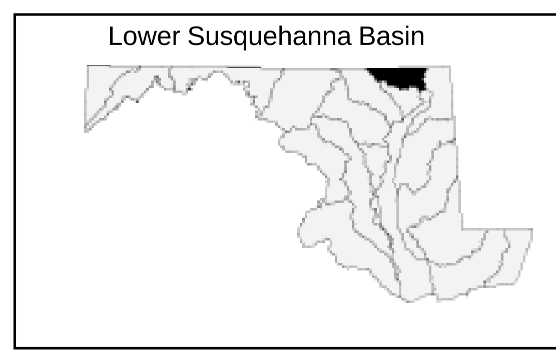
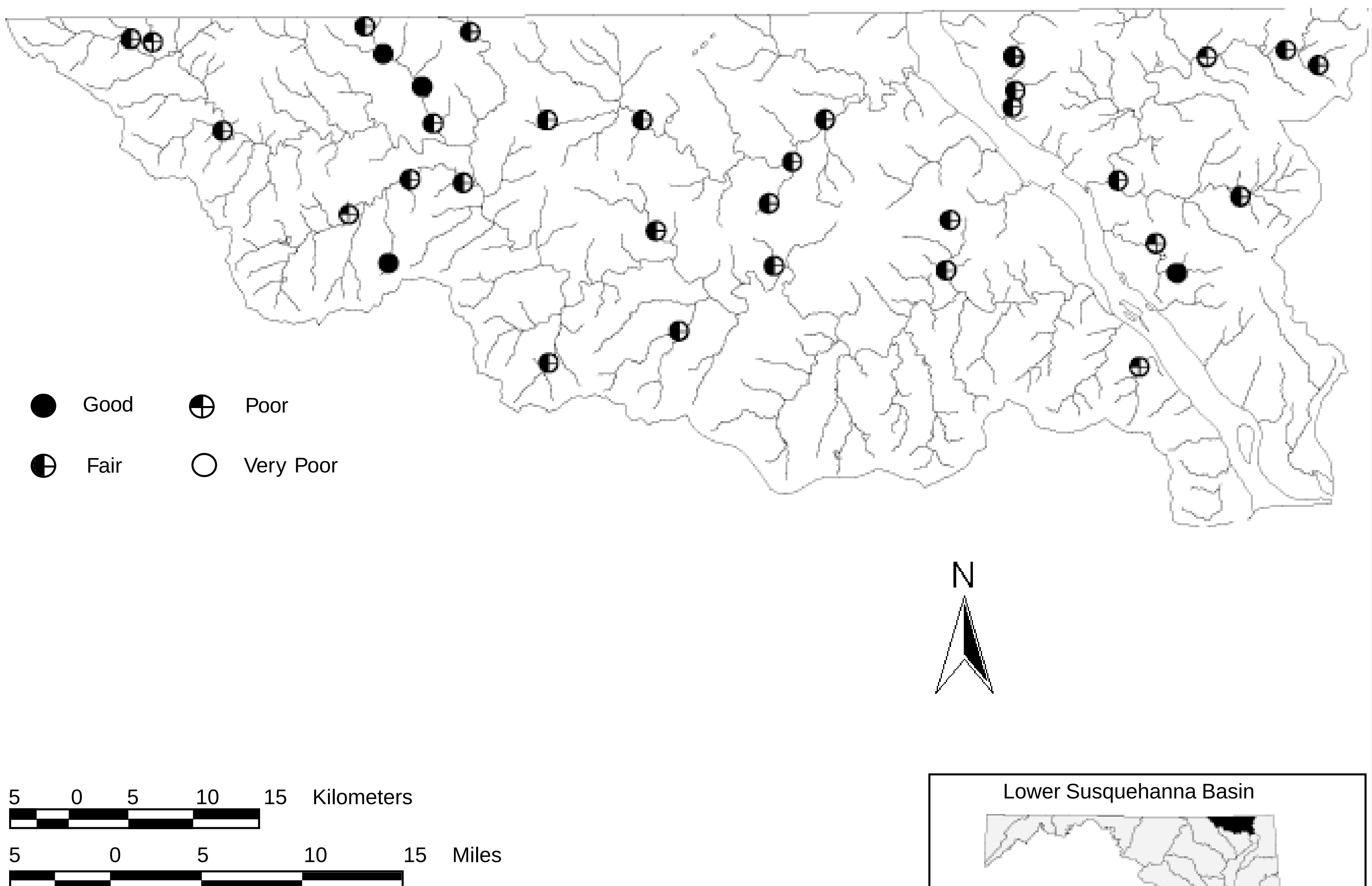


Figure 14. Stream ecological conditions in the Lower Susquehanna basin based on the fish Index of Biotic Integrity (F-IBI), 1997.



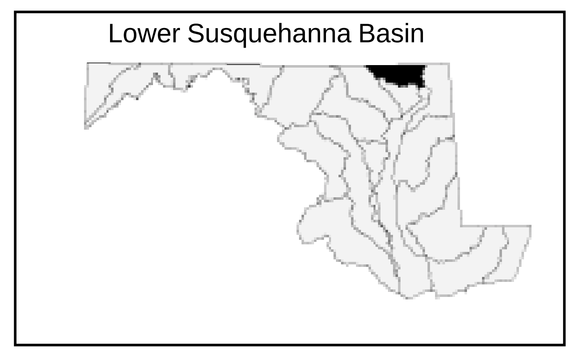


Figure 15. Stream ecological conditions in the Lower Susquehanna basin based on the benthic macroinvertebrate Index of Biotic Integrity (B-IBI), 1997.

the analysis. However, benthic macroinvertebrates are less affected by these conditions and thus were not limited by the size of the watershed. The discrepancy between the indices may be attributed to several factors, including each IBI's classification rating, differences in response to environmental stress between fish and benthic macroinvertebrates, and the number of sites asssessed by each IBI. A detailed discussion of these factors is presented in Chapter 5.

REPTILES AND AMPHIBIANS

Reptiles and amphibians were found at 63 of the 67 sites sampled in 1994 and 1997. Salamanders were the most commonly encountered group, occurring at approximately seventy percent of the sites. However, the dominance of this group is attributed to the occurrence of Northern two-lined salamanders which, at 64 percent of the sites, were the most common species collected (Table 2). Frogs and toads were found at sixty-six percent of the sites. However, in contrast to salamanders their high occurence is due to the presence of several species. Turtles and snakes were found at 24 and 10 percent of the sites, respectively.

FRESHWATER MUSSELS

Freshwater mussels were rare in the Lower Susquehanna basin. One species, the Asiatic clam (*Corbicula fluminea*) was collected and occurred at only five of the 35 sites sampled. This species was found in the larger, third-order sites of Conowingo Creek (4 sites) and Stone Run (1 site).

Table 2. List of herpetofauna observed in the Lower Susquehanna basin, 1994 and 1997.

Frogs and Toads	Frequency of Occurrence (%)
American Toad *Bufo americanus*	16.4
Bullfrog *Rana catesbeiana*	28.4
Fowler's Toad *Bufo woodhousii fowleri*	8.9
Green Frog *Rana clamitans melanota*	23.9
Pickerel Frog *Rana palustris*	29.8
Wood Frog *Rana sylvatica*	7.5
Turtles	
Common Snapping Turtle *Chelydra serpentina serpentina*	11.9
Eastern Box Turtle *Terrapene carolina carolina*	11.9
Wood Turtle *Clemmys insculpta*	7.5
Snakes	
Black Rat Snake *Elaphe obsoleta obsoleta*	1.5
Eastern Garter Snake *Thamnophis s. sirtalis*	1.5
Northern Water Snake *Nerodia sipedon sipedon*	10.4
Salamanders	
Northern Dusky Salamander *Desmognathus fuscus fuscus*	7.5
Northern Two-Lined Salamander *Eurycea bislineata*	64.2
Red Salamander *Pseudotriton ruber*	8.9
Redback Salamander *Plethodon cinereus*	7.5

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Information from the Maryland Biological Stream Survey in 1997 has provided us with a snapshot of living resources, stream conditions, and major stressors to the aquatic habitat of the Lower Susquehanna basin. Like most Maryland watersheds, the Lower Susquehanna consists of a network of streams that range in quality from degraded to relatively healthy. MBSS' one-time measurements of dissolved oxygen, pH, and acid neutralizing capacity indicate that most streams have acceptable levels of water quality and no violations of state water quality standards. However, elevated nitrate-nitrogen levels were common throughout the basin (>94% of all stream miles) and were clearly related to the proportion of agricultural land (Figures 16 and 17; next page). Of the ten sites with nitrate-nitrogen levels greater than 5.0 mg/L, four were within the Conowingo Creek watershed. Values at these sites ranged from 6.6 to 8.3 mg/L.

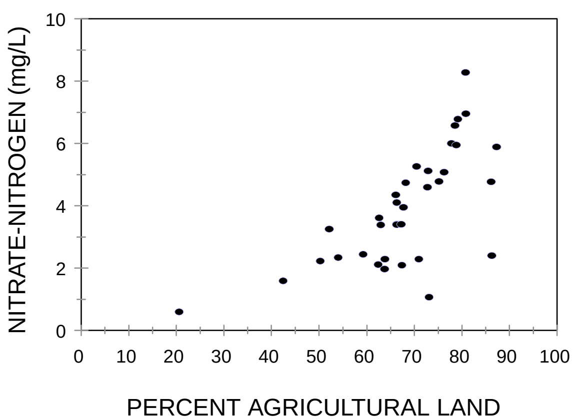

Figure 16. Nitrate-nitrogen and the percent agricultural land use at MBSS sampling sites in the Lower Susquehanna basin (1997).

Because MBSS sampling is conducted under baseflow conditions, these results suggest that groundwater is a chronic, large-scale source of nitrogen. This conclusion is supported by Lindsey et al. (1998) who found that despite a general decrease in total nitrogen throughout the basin, nitrate-nitrogen levels have remained constant. The reduction of total nitrogen is largely due to improvements of sewage treatment plants and the implementation of best-management practices, however non-point and groundwater sources remain. With elevated nutrient conditions so widespread, reducing inputs to a few of the worst streams is unlikely to correct the problem, instead a general reduction of nitrogen loading throughout the basin is necessary.

Although all streams in the basin met state water quality standards (a result common to other surveys which only measure water chemistry), there is evidence of biological impairment. The MDNR's fish Index of Biotic Integrity classified over 20% of the stream miles as Poor or Very Poor. The benthic IBI did not rate any stream miles Very Poor, but it did indicate a similar number of streams miles in Poor condition (approximately 13%). Also, the majority of sites classified as Fair scored within the lower range of that category and are therefore susceptible to being degraded to Poor condition. Unlike other basins, IBI scores of the Lower Susquehanna do not exhibit any trends with associated landuse practices. Typically, IBIs are inversely related to urban landuse, but given that urbaniztion is not widespread in the basin this relationship was not apparent.

The discrepancy of the ratings between the IBIs may be attributed to several factors. First, the classification effiencies of the fish and benthic IBIs are 82% and 88%, respectively. The error associated with each index likely accounts for some of the disagreement. Second, it has been established that because of differences in trophic level, life history patterns, and responses to environmental stressors, fish and benthic macroinvertebrates reflect different types of environmental perturbations. Fish generally respond to larger, landscape scale influences while the benthic macroinvertbrate community reflects water chemistry and instream habitat. Finally, nearly one-quarter of the streams miles could not be assessed by the fish IBI because of the minumum 300 acre watershed size criterion. The difference in the number of sites assessed by each IBI could affect the overall evaluation of the basin, particularly because these unassessed first and second-order streams make up 78 percent of the total stream miles.

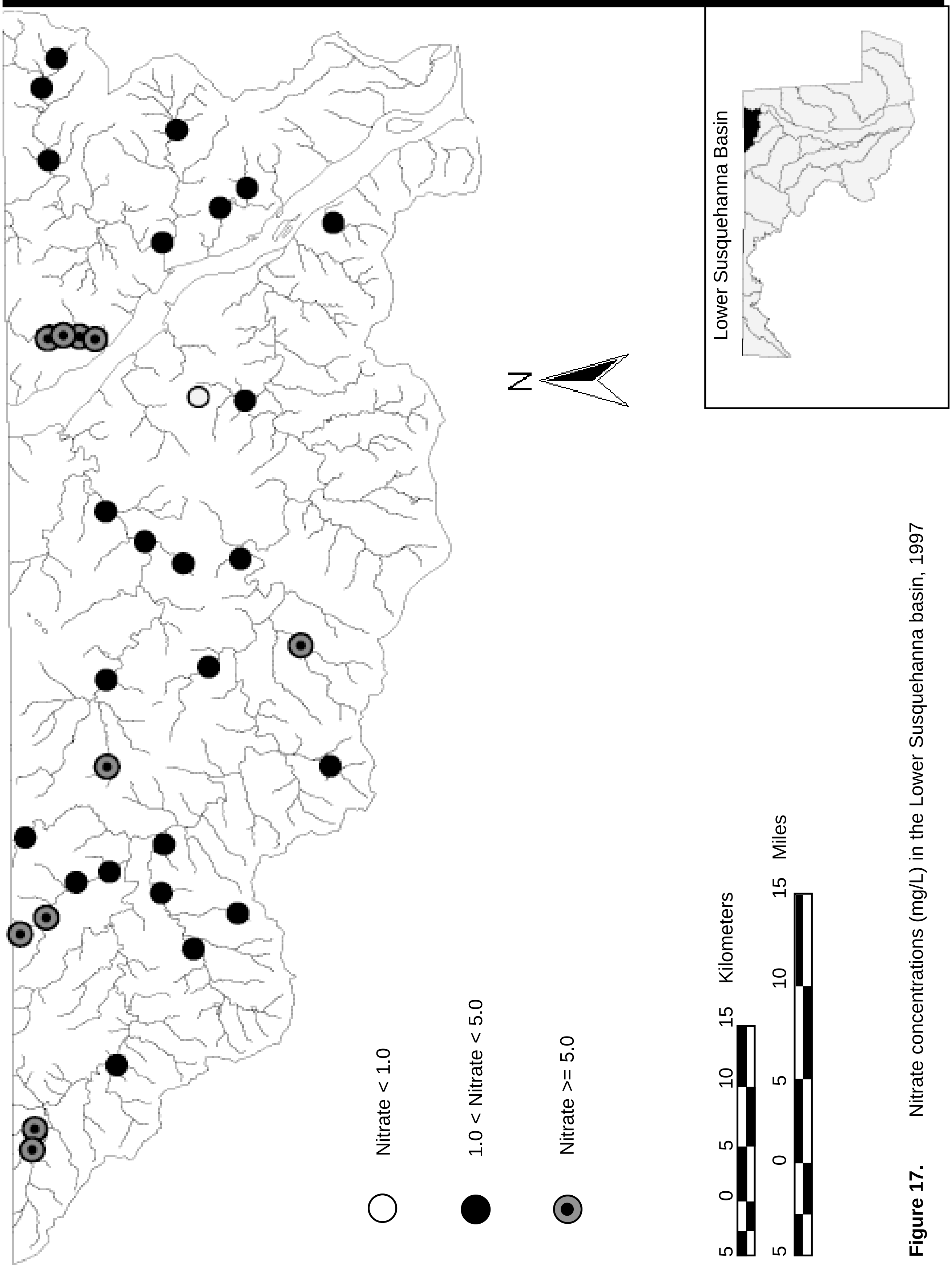

Figure 17. Nitrate concentrations (mg/L) in the Lower Susquehanna basin, 1997

Approximately 20% of streams in the basin appear to be in Good condition based on the physical habitat index, however, almost 30% of the stream miles are degraded. This degradation is largely the result of a lack of rootwads and woody debris, unstable stream banks and excessive siltation, modification of the stream channel (e.g., channelization), and loss of functional riparian buffer zones. Large woody debris and rootwads function to reduce the erosive power of water. Without these natural structures, the problem of bank instability, and subsequent soil loss, intensifies. Nearly 35% of all stream miles in the basin have unstable or moderately unstable stream banks. Unstable bank conditions increase the amount of sediment that enters the stream and, in turn, increases siltation of rocks and gravel, reducing habitat available for benthos and food supplies for fish. This problem is further compounded in streams that experience greater runoff due to land use changes that increase the amount of impervious surface, a growing problem in the Lower Susquehanna basin. Lastly, one-quarter of the streams in the basin have no functional (vegetated) riparian buffer on at least one side of the stream, thereby reducing the ecological integrity of the stream and threatening downstream areas. The lack of protective vegetation along streams is an obvious starting point in the restoration process because riparian buffers improve both water quality and physical habitat. In general, results of the MBSS suggest that physical habitat degradation is an important, widespread problem in the Lower Susquehanna basin.

Fish community diversity in non-tidal streams of the Lower Susquehanna is among the highest of the state's eighteen river basins. Thirteen of the 61 species of fish collected are non-native, and most, if not all, of these species were introduced by fishery managers or anglers. From a recreational standpoint, some of these introductions have been beneficial, but ecological impacts, such as the reduction in distribution and abundance of native species, have occurred and will continue. Unfortunately, there is little historical information about fish communities composition in the basin. Therefore, it is difficult to determine if the introduction of non-native fishes has influenced the distribution and abundance of native species. The MBSS results establish a useful benchmark of current fish species composition, distribution, and abundance that can be used to track future changes. Because of the recognized potential for detrimental effects, the Chesapeake Bay states have started a review process for proposed introductions of non-native species that should reduce the number of unwise introductions.

Five species of gamefish were present: brook trout, brown trout, rainbow trout, smallmouth bass, and largemouth bass. Brook trout, the only native species, were the most abundant gamefish and along with brown trout and smallmouth bass maintain the second highest densities of these species in the state. Rainbow trout were only collected at qualitative sites and therefore are not included in the population estimates. Brook and brown trout were the only species captured which were of harvestable size, comprising approximately 10% and 20% of the total catch of each species, respectively. Largemouth bass and smallmouth bass were all smaller than the legal size limit. These findings are likely the result of the spring stocking of legal trout and the timing of MBSS sampling, which coincides with the juvenile stages of bass. Additionally, adult largemouth and smallmouth bass prefer larger tributaries and would probably not inhabit the smaller first through third-order streams which MBSS samples. Although not documented, the impact of these non-native gamefish has probably affected the native fish community structure, both in terms of the distribution and abundance of species.

American eel, sea lamprey, and white perch were the only migratory species that were collected in the Lower Susquehanna basin. Of these, American eel were the most abundant with approximately 67 per stream mile. Other migratory fishes such as striped bass, American shad, and blueback herring, are common throughout the basin but were not found in the smaller tributaries that the MBSS samples. The basin has 52 known barriers to fish migration (MDNR 1999; Figure 18). The prevalent blockages are dams, and the majority are found on tributary streams. However, there are large impoundments such as Conowingo Dam on the mainstem of the Susquehanna River which, despite fish passage facilities, slow or block the movement of fishes. With future expansion of housing and other development in the basin, the number of barriers (e.g., pipe crossings and culverts) will likely increase as more roads and sewage systems are constructed, thus reducing the amount of habitat accessible to migratory fish.

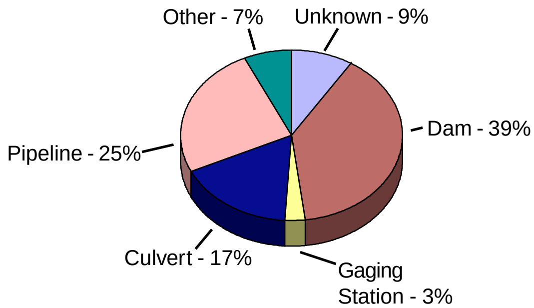

Figure 18. Barriers to fish migration in the Lower Susquehanna basin, 1997. Expressed as a percentage of the total (52).

The amount rain and snow falling onto a watershed is an important factor in shaping the biological community of a stream. Dry, low flow periods are considered stressful for stream life due to higher water temperatures, low dissolved oxygen levels, and reduction in the amount of available habitat. Conversely, extremely heavy rainfall and high flows from increased watershed imperviousness may result in large-scale changes in physical habitat, temporarily lethal water quality conditions, mortality of bottom species because of crushing by moving rocks, and transport of aquatic animals to less favorable habitat.

In 1997, total rainfall in the Lower Susquehanna basin was about 16% lower than average (NOAA 1997; Figure 19). Only 2 months, March and November, had above average rainfall. The extremely dry periods during May and June may have caused significant stress to stream biota, resulting in reductions in species richness and abundance of fish and benthic macroinvertebrates. Without long-term data on rainfall, flow, and stream ecological conditions, it is difficult to determine relationships among these environmental factors and stream quality. When the MBSS is repeated in future years, more light should be shed on this important subject.

Given the type and magnitude of stream impacts noted in 1997 and the projected changes in land use, human population size, and water demands in the Lower Susquehanna basin, the biological communities and other ecological attributes of streams in the basin will likely become more degraded in years to come. Comprehensive implementation of best-management practices (BMPs), such as riparian zone protection and reforestation, may partially offset these impacts. However, it is important to note that BMPs may reduce, but do not eliminate the ecological impacts of human disturbance.

This report helps illustrate that some valuable stream resources still exist. However, in many ways the Lower Susquehanna still suffers from mistakes of the past. The entire basin has been logged, including riparian zones, and as a result unstable stream channels are common, physical habitat is greatly reduced, and even forested streams now carry elevated sediment loads. In addition, a network of dams and other migration barriers exclude many species of fish from useable stream habitat. In more urbanized areas, large volumes of water flush directly into streams during storms and baseflows are reduced to a trickle during dry periods. These extreme fluctuations in flow create conditions that only the hardiest aquatic animals can tolerate. All of these problems can be lessened or eliminated, but great cost is typically involved. Over time, we must work to restore conditions in the basin for future generations. At the same time, however, we also need to make a concerted effort to protect and enhance the remaining high quality resources in the basin and elsewhere in Maryland. Only in this way can we learn to exist in a sustainable manner.

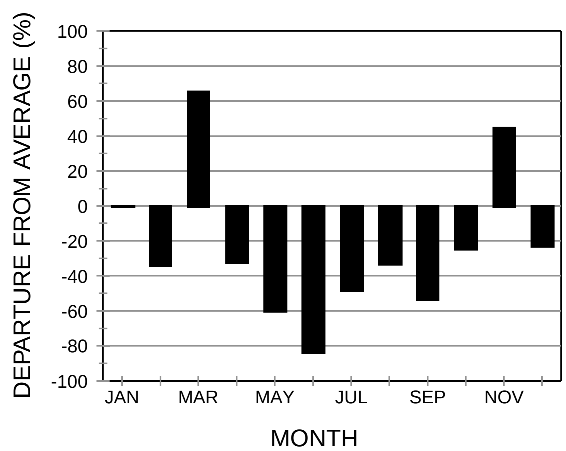

Figure 19. Monthly rainfall in the Lower Susquehanna basin (1997). Bars indicate the departure, expressed as a percentage, from the average monthly rainfall from 1965 through 1995.

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SYNOPSIS OF MBSS DESIGN AND SAMPLING METHODS

The MBSS is intended to provide unbiased estimates of the condition of streams and rivers of Maryland on a local (e.g., drainage basin or county) as well as a statewide scale. To date, the MBSS has focused on wadeable, headwater streams. The survey is based on a probabilistic stream sampling approach where random selections are made from all sections of streams in the state which can physically be sampled. The approach supports statistically-valid population estimation of variables of interest (e.g., largemouth bass densities, miles of streams with degraded physical habitat, etc.). When repeated, the MBSS will also provide a basis for assessing future changes in ecological condition of flowing waters of the state. At present, plans are to continue the MBSS and develop a quantitative sampling approach for larger streams and rivers.

The study area for the MBSS includes each of the 18 major drainage basins of the state, and a total of three years was required to sample all 18 basins. For logistical reasons, the state was divided into three geographic regions (east, west, and central) with five to seven basins in each region. Each basin was sampled at least once during the three year cycle, and one basin in each region was sampled twice so that data collected in different years could be combined into a single statewide estimate for each of the variables of interest.

The sampling frame for the MBSS was constructed by overlaying basin boundaries on a map of all blueline stream reaches in the state as digitized on a U.S. Geological Survey 1:250,000 scale map. Sampling within basins was restricted to non-tidal, first, second and third-order (Strahler 1964) stream reaches, excluding unwadeable or otherwise unsampleable areas. An additional restriction was that only public land or privately-owned sites where landowner permissions was obtained were sampled.

During 1995 the MBSS sample sites were selected from a comprehensive list of headwater stream reaches in 6 of the 18 drainage basins. In 1996, sample sites were selected from 7 basins, and in 1997 the remaining basins were sampled. To provide adequate information about each size of stream, an approximately equal number of first, second and third-order streams were sampled during spring and summer, with the number of sites of each order in a basin being proportional to the number of stream miles (of an order) in the entire state.

Benthic macroinvertebrates and water quality samples were collected during the spring index period from March through early May, while fish, herpetofauna, *in situ* stream chemistry and physical habitat sampling were conducted during the low flow period in the summer, from June through September.

In the spring, water samples were collected and analyzed for pH, acid-neutralizing capacity (ANC), sulfate (SO_4), nitrate (NO_3), conductivity, and dissolved organic carbon (DOC) in the laboratory. These variables primarily characterize the sensitivity of the streams to acid deposition, and to other anthropogenic stressors to a lesser extent. Benthic macroinvertebrates collected in the spring were identified to family and genus level in the laboratory.

Habitat assessments were conducted in the summer using metrics largely patterned after EPA's Rapid Bioassessment Protocols and Ohio EPA's Qualitative Habitat Evaluation Index (QHEI) described by Rankin (1989), Plafkin *et al.* (1989), and Platts *et al.* (1983) in the designated 75 m length of the stream segments; riparian habitat measurements were based on the surrounding area within 20 m of the segment. Other qualitative measurements included (1) aesthetic value, based on evidence of human refuse; (2) remoteness, based on the absence of detectable human activity and difficulty in accessing the segment; (3) land use, based on the surrounding area immediately visible from the segment; (4) general stream character, based on the shape, substrate, and vegetation of the segment; and (5) bank erosion, based on the kind and extent of erosion present. Quantitative measurements at each segment included flow, depth, wetted width, and stream gradient.

Fish and herpetofauna were sampled during the summer index period using quantitative, double-pass electrofishing of the 75 m stream segments. Blocking nets were placed at each end of the segment, and one or more direct-current, backpack electrofishing units were used to sample the entire segment. All fish captured during each electrofishing pass were identified, counted, weighed in aggregate, and up to 100 individuals of each species were examined for external anomalies such as lesions and tumors. All gamefish captured were also measured for length. Any amphibians, reptiles, freshwater molluscs, submerged aquatic vegetation either in or near the stream segment were collected and identified.

For all phases of the MBSS, there was a ongoing, documented program of quality assurance/quality control (QA/QC). The QA/QC program used by the MBSS allows for generation of data with known confidence.

STREAMS SAMPLED IN THE LOWER SUSQUEHANNA BASIN IN 1997 AS PART OF THE MARYLAND BIOLOGICAL STREAM SURVEY (MBSS) (QUANTITATIVE SAMPLES ONLY)

As described in Chapter 3 and Appendix B, MBSS sampling sites were selected randomly from 1:250,000 scale maps. Many very small streams were selected--some with names and some without. Stream names were acquired for the MBSS database from several map sources. Those streams with no names are called unnamed tributaries.

Stream Name	Order	Stream Name	Order
Big Branch	1	Big Branch (3 sites)	2
Falling Branch	1	Cabbage Run	2
Hing Run	1	Deer Creek	2
Holland's Branch	1	Holland Branch	2
Jack's Hole	1	Little Deer Creek (2 sites)	2
Rock Run	1	Mine Branch	2
South Stirrup Run	1	Plumtree Branch	2
Unnamed Trib. to Broad Creek	1	Broad Creek (3 sites)	3
Unnamed Trib. to Deer Creek	1	Conowingo Creek (4 sites)	3
Unnamed Trib. to Deer Creek	1	Deer Creek	3
Unnamed Trib. to Stone Run	1	Ebaugh's Creek	3
Unnamed Trib. to Susquehanna R.	1	Stone Creek (2 sites)	3
Basin Run (2 sites)	2		

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Appendix C: Location and water quality data for MBSS sites in the Lower Susquehanna basin, 1997. Temperature and Dissolved Oxygen (DO) were measured in the summer while all other parameters were measured during the spring. Units of measure for temperature are degrees celcius. DO, nitrate nitrogen (NO_3), sulfate (SO_4), and dissolved organic carbon (DOC) are presented in mg/L, and acid neutralizing capacity (ANC) is measured as μeq/L.

Stream Name	Latitude	Longitude	Temp.	DO	pH	ANC	NO_3	SO_4	DOC
Ebaugh's Creek	39.7120	76.5900	15.8	9.6	7.3	399.5	5.1	7.4	1.7
Deer Creek	39.7130	76.6000	19.0	9.9	7.4	517.4	5.2	6.3	1.1
Stone Run	39.7060	76.0670	25.7	6.5	7.4	913.4	2.0	11.6	5.4
Basin Run	39.6600	76.1450	19.2	9.3	7.5	573.2	2.4	16.8	4.4
Conowingo Creek	39.6930	76.1920	21.9	10.0	7.7	736.0	6.7	15.0	4.0
Conowingo Creek	39.7050	76.1930	24.1	8.5	7.6	774.2	6.9	14.9	4.0
Conowingo Creek	39.7050	76.1920	24.1	8.5	8.0	628.3	8.2	13.9	2.0
Basin Run	39.6540	76.0880	15.3	9.6	7.0	540.1	2.2	16.7	4.5
UT* to Susquehanna River	39.6380	76.1270	16.2	10.1	6.7	361.7	2.2	12.4	7.3
Stone Run	39.7040	76.1030	15.1	10.1	7.6	890.0	3.9	6.9	1.1
UT* to Stone Run	39.7010	76.0520	23.7	5.4	7.3	917.6	2.4	12.3	9.3
Conowingo Creek	39.6870	76.1930	21.1	8.8	7.5	793.4	6.5	14.8	5.1
Rock Run	39.6270	76.1180	13.1	9.9	6.9	329.6	1.9	12.5	4.0
Big Branch	39.7070	76.4830	17.6	10.1	7.0	223.1	6.0	4.6	0.5
South Stirrup Run	39.5970	76.4080	17.5	9.6	7.1	322.6	2.1	10.9	1.6
Mine Branch	39.6440	76.3580	13.4	10.6	7.1	329.0	3.3	7.0	1.9
Herring Run	39.5940	76.1360	15.2	9.5	7.2	389.8	1.9	13.6	2.6
Little Deer Creek	39.6630	76.4710	20.5	9.6	7.2	415.5	3.4	9.2	1.3
Little Deer Creek	39.6610	76.4470	17.6	10.6	7.2	458.6	3.3	9.8	1.4
Plumtree Branch	39.6800	76.5570	16.4	9.7	7.2	319.5	3.4	6.5	1.2
Jacks Hole	39.6830	76.4080	15.9	9.8	6.9	466.5	5.8	11.2	1.1
Big Branch	39.7170	76.4920	20.0	9.8	6.9	258.1	5.9	5.6	1.0
Broad Creek	39.6830	76.3640	17.9	11.1	7.1	313.0	4.7	8.7	1.7
Cabbage Run	39.6080	76.3480	12.7	10.5	7.2	389.1	5.0	12.2	1.1
Holland's Branch	39.6470	76.2220	15.5	7.7	7.1	395.0	0.5	11.3	3.4
Deer Creek	39.6500	76.4990	18.1	9.2	7.1	432.8	1.0	28.0	1.4
UT* to Deer Creek	39.6310	76.3040	14.8	9.8	7.5	925.5	2.2	11.3	1.0
Broad Creek	39.6830	76.2800	17.0	9.4	7.2	382.1	3.6	8.0	1.3
UT* to Broad Creek	39.6530	76.3060	16.0	9.3	6.9	340.5	4.7	10.2	0.8
UT* to Deer Creek	39.6330	76.4810	18.5	8.9	6.8	279.4	3.2	5.1	1.7
Big Branch	39.6960	76.4650	16.5	10.0	7.1	258.9	4.5	6.1	1.4
Big Branch	39.6830	76.4600	16.7	9.4	7.2	247.8	4.1	5.6	1.2
Falling Branch	39.7150	76.4430	17.8	9.6	7.0	314.6	4.7	6.0	1.9
Broad Creek	39.6680	76.2950	21.1	9.7	7.3	294.5	4.3	7.2	1.1
Holland Branch	39.6290	76.2240	12.0	10.5	7.5	671.6	2.3	11.4	2.3

***UT = Unnamed Tributary**

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PHYSICAL HABITAT CONDITIONS MEASURED BY THE MBSS

I. SUBSTRATE AND INSTREAM COVER

Instream Habitat is rated according to the perceived value of habitat to the fish community. Higher scores are assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores are assigned to sites with a high degree of uneven substrate. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.

Epifaunal Substrate is rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, flocculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

Velocity/Depth Diversity is rated based on the variety of velocity/depth regimes present at a site (slow-shallow, slow-deep, fast-shallow, and fast-deep). As with embeddedness, this metric may result in lower scores in low-gradient streams but will provide statewide information on the physical habitat found in Maryland streams.

Pool/Glide/Eddy Quality is rated based on the variety and spatial complexity of slow or still water habitat within the sample segment. In high-gradient streams, functionally important slow water habitat may exist in the form of larger eddies. Within a category, higher scores are assigned to segments which have undercut banks, woody debris or other types of cover for fish.

Riffle/Run Quality is based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

Embeddedness is a percentage of surface area of larger particles that is surrounded by fine sediments on the stream bottom. In low gradient streams, embeddedness may be high even in unimpaired streams.

II. CHANNEL CHARACTER

Channel Alteration is a measure of large-scale changes in the shape of the stream channel. Channel alteration includes: concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures, as well as recent bar development. Ratings for this metric are based on the presence of artificial structures as well as the existence, extent, and coarseness of point bars, side bars, and mid-channel bars which indicate the degree of flow fluctuations and substrate stability. Evidence of channelization may sometimes be seen in the form of berms which parallel the stream channel.

Bank Stability is rated based on the presence/absence of riparian vegetation and other stabilizing bank materials such as boulders and rootwads, and frequency/size of erosional areas. Sites with steep slopes are not penalized if banks are composed solely of stable materials.

Channel Flow Status is the percentage of the stream channel that has water, with subtractions made for exposed substrates and dewatered areas.

III. RIPARIAN CORRIDOR

Shading is rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by land forms.

Riparian Buffer is rated according to the size and type of the vegetated riparian buffer zone at the site. Cultivated fields for agriculture which have bare soil to any extent are not considered as riparian buffers. At sites where the buffer width is variable or direct delivery of storm runoff or sediment to the stream is evident or highly likely, the narrowest representative buffer width in the segment (e.g., 0 if parking lot runoff enters directly to the stream) is measured and recorded even though some of the stream segment may have a well developed riparian buffer.

IV. AESTHETICS/REMOTENESS

Aesthetics are rated according to the visual appeal of the site and presence/absence of human refuse, with highest scores assigned to stream segments with no human refuse and visually outstanding character.

Remoteness is rated based on the absence of detectable human activity and difficulty in accessing the segment.

MBSS Habitat Assessment Guidance Sheet

Habitat Parameter	Optimal 16-20	Sub-Optimal 11-15	Marginal 6-10	Poor 0-5
1. Instream Habitat[a]	Greater than 50% mix of a variety of cobble, boulder, submerged logs, undercut banks, snags, rootwads, aquatic plants, or other stable habitat	30-50% mix of stable habitat. Adequate habitat	10-30% mix of stable habitat. Habitat availability less than desirable	Less than 10% stable habitat. Lack of habitat is obvious
2. Epifaunal Substrate[b]	Preferred substrate abundant, stable, and at full colonization potential (riffles well developed and dominated by cobble; and/or woody debris prevalent, not new, and not transient)	Abund. of cobble with gravel &/or boulders common; or woody debris, aquatic veg., under-cut banks, or other pro-ductive surfaces common but not prevalent /suited for full colonization	Large boulders and/or bedrock prevalent; cobble, woody debris, or other preferred surfaces uncommon	Stable substrate lacking; or particles are over 75% surrounded by fine sediment or flocculent material
3. Velocity/Depth Diversity[c]	Slow (<0.3 m/s), deep (>0.5 m); slow, shallow (<0.5 m); fast (>0.3 m/s), deep; fast, shallow habitats all present	Only 3 of the 4 habitat categories present	Only 2 of the 4 habitat categories present	Dominated by 1 velocity/depth category (usually pools)
4. Pool/Glide/Eddy Quality[d]	>50% pool/glide/eddy habitat; both deep (>.5 m)/shallows (<.2 m) present; complex cover/&/or depth >1.5 m	10-50% pool/glide/eddy habitat, with deep (>0.5 m) areas present; or >50% slow water with little cover	<10% pool/glide/eddy habitat, with shallows (<0.2 m) prevalent; slow water areas with little cover	Pool/glide/eddy habitat minimal, with max depth <0.2 m, or absent completely
5. Riffle Quality[e]	Riffle/run depth generally >10 cm, with maximum depth greater than 50 cm (maximum score); substrate stable (e.g. cobble, boulder) & variety of current velocities	Riffle/run depth generally 5-10 cm, variety of current velocities	Riffle/run depth generally 1-5 cm; primarily a single current velocity	Riffle/run depth < 1 cm; or riffle/run substrates concreted
6. Channel Alteration[f]	Little or no enlargement of islands or point bars; no evidence of channel straightening or dredging; 0-10% of stream banks artificially armored or lined	Bar formation, mostly from coarse gravel; and/or 10-40% of stream banks artificially armored or obviously channelized	Recent but moderate deposition of gravel and coarse sand on bars; and/or embankments on both banks; and/or 40-80% of banks artificially armored; or channel lined in concrete	Heavy deposits of fine material, extensive bar development; OR recent channelization or dredging evident; or over 80% of banks artificially armored
7. Bank Stability[g]	Upper bank stable, 0-10% of banks with erosional scars and little potential for future problems	Moderately stable. 10-30% of banks with erosional scars, mostly healed over. Slight potential in extreme floods	Moderately unstable. 30-60% of banks with erosional scars and high erosion potential during extreme high flow	Unstable. Many eroded areas. "Raw" areas frequent along straight sections and bends. Side slopes >60° common
8. Embeddedness[h]	Percentage that gravel, cobble, and boulder particles are surrounded by line sediment or flocculent material.			
9. Channel Flow Status[i]	Percentage that water fills available channel			
10. Shading[j]	Percentage of segment that is shaded (duration is considered in scoring). 0% = fully exposed to sunlight all day in summer; 100% = fully and densely shaded all day in summer			
11. Riparian Buffer[k]	Minimum width of vegetated buffer in meters; 50 meters maximum; see back of Habitat Assessment Data Sheet for buffer type and land cover immediately adjacent to buffer			

Habitat Parameter	Optimal (16-20)	Sub-Optimal (11-15)	Marginal (6-10)	Poor (0-5)
12. Aesthetic Rating[l]	Little or no evidence of human refuse present; vegetation visible from stream essentially in a natural state	Human refuse present in minor amounts; and/or channelization present but not readily apparent; and/or minor disturbance of riparian vegetation	Refuse present in moderate amounts; and/or channel-ization readily apparent; and/or moderate disturbance of riparian vegetation	Human refuse abundant and un-sightly: and/or extensive unnatural channelization; and/or nearly complete lack of vegetation
13. Remoteness[m]	Stream segment more than 1/4 mile from nearest road; access difficult and little or no evidence of human activity	Stream segment within 1/4 of but not immediately accessible to roadside access by trail; site with moderately wild character	Stream within 1/4 mile of roadside and accessible by trail; anthropogenic activities readily evident	Segment immediately adjacent to roadside access; visual , olfactory, and/or auditory displeasure experienced

a) **Instream Habitat** Rated based on perceived value of habitat to the fish community. Within each category, higher scores should be assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores should be assigned to sites with a high degree of hypsographic complexity (uneven bottom). In streams where ferric hydroxide is present, instream habitat scores are not lowered unless the precipitate has changed the gross physical nature of the substrate. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.

b) **Epifaunal Substrate** Rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, floculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

c) **Velocity/Depth Diversity** Rated based on the variety of velocity/depth regimes present at a site (slow-shallow, slow-deep, fast-shallow, and fast-deep). As with embeddedness, this metric may result in lower scores in low-gradient streams but will provide a statewide information on the physical habitat found in Maryland streams.

d) **Pool/Glide/Eddy Quality** Rated based on the variety and spatial complexity of slow- or still-water habitat within the sample segment. It should be noted that even in high-gradient segments, functionally important slow-water habitat may exist in the form of larger eddies. Within a category, higher scores are assigned to segments which have undercut banks, woody debris or other types of cover for fish.

e) **Riffle/Run Quality** Rated based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

f) **Channel Alteration** Is a measure of large-scale changes in the shape of the stream channel. Channel alteration includes: concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures, as well as recent bar development. Ratings for this metric are based on the presence of artificial structures as well as the existence, extent, and coarseness of point bars, side bars, and mid-channel bars which indicate the degree of flow fluctuations and substrate stability. Evidence of channelization may sometimes be seen in the form of berms which parallel the stream channel.

g) **Bank Stability** Rated based on the presence/absence of riparian vegetation and other stabilizing bank materials such as boulders and rootwads, and frequency/size of erosional areas. Sites with steep slopes are not penalized if banks are composed solely of stable materials.

h) **Embeddedness** Rated as a percentage based on the fraction of surface area of larger particles that is surrounded by fine sediments on the stream bottom. In low gradient streams with substantial natural deposition, the correlation between embeddedness and fishability or ecological health may be weak or non-existent, but this metric is rated in all streams to provide similar information from all sites statewide.

i) **Channel Flow Status** Rated based on the percentage of the stream channel that has water, with subtractions made for exposed substrates and islands.

j) **Shading** Rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by landforms.

k) **Riparian Buffer Zone** Based on the size and type of the vegetated riparian buffer zone at the site. Cultivated fields for agriculture which have bare soil to any extent are not considered as riparian buffers. At sites where the buffer width is variable or direct delivery of storm runoff or sediment to the stream is evident or highly likely, the smallest buffer in the segment. (e.g., 0 if parking lot runoff enters directly to the stream) is measured and recorded even though some of the segment may have a well developed buffer. In cases where the riparian zone on one side of the stream slopes away from the stream and there is no direct point of entry for runoff, the buffer on the other side of the stream should be measured and recorded and a comment made in comments section of the data sheet.

l) **Aesthetic Rating** Rated based on the visual appeal of the site and presence/absence of human refuse, with highest scores assigned to stream segments with no human refuse and visually outstanding character.

m) **Remoteness** Rated based on the absence of detectable human activity and difficulty in accessing the segment.

Stream Name	Latitude	Longitude	Instream Habitat	Epifaunal Substrate	Velocity/ Depth	Pool Quality	Riffle Quality
Ebaugh's Creek	39.7120	76.5900	14	11	17	18	15
Deer Creek	39.7130	76.6000	17	15	17	17	16
Stone Run	39.7060	76.0670	14	12	13	18	13
Basin Run	39.6600	76.1450	18	14	17	15	18
Conowingo Creek	39.6930	76.1920	18	17	16	16	17
Conowingo Creek	39.7050	76.1930	19	9	18	18	19
Conowingo Creek	39.7050	76.1920	17	7	15	17	5
Basin Run	39.6540	76.0880	14	15	17	16	15
UT* to Susquehanna River	39.6380	76.1270	15	13	6	13	8
Stone Run	39.7040	76.1030	18	15	18	19	15
UT* to Stone Run	39.7010	76.0520	12	10	11	11	11
Conowingo Creek	39.6870	76.1930	16	16	18	15	17
Rock Run	39.6270	76.1180	18	15	10	15	11
Big Branch	39.7070	76.4830	17	16	14	17	13
South Stirrup Run	39.5970	76.4080	16	18	11	16	8
Mine Branch	39.6440	76.3580	17	16	17	16	16
Herring Run	39.5940	76.1360	17	17	7	13	11
Little Deer Creek	39.6630	76.4710	19	17	19	17	18
Little Deer Creek	39.6610	76.4470	12	12	17	19	5
Plumtree Branch	39.6800	76.5570	18	15	8	13	16
Jacks Hole	39.6830	76.4080	15	17	8	15	10
Big Branch	39.7170	76.4920	16	13	13	18	14
Broad Creek	39.6830	76.3640	16	17	18	16	16
Cabbage Run	39.6080	76.3480	17	18	17	17	14
Holland Branch	39.6470	76.2220	16	11	1	5	1
Deer Creek	39.6500	76.4990	15	14	18	18	16
UT* to Deer Creek	39.6310	76.3040	14	13	7	10	16
Broad Creek	39.6830	76.2800	16	15	13	15	5
UT* to Broad Creek	39.6530	76.3060	10	9	8	10	10
UT* to Deer Creek	39.6330	76.4810	17	16	13	17	14
Big Branch	39.6960	76.4650	16	16	14	12	16
Big Branch	39.6830	76.4600	18	18	18	16	18
Falling Branch	39.7150	76.4430	16	13	12	17	14
Broad Creek	39.6680	76.2950	18	10	18	16	5
Holland Branch	39.6290	76.2240	19	18	16	17	15

*** UT - Unnamed Tributary**

Stream Name	Latitude	Longitude	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow (%)
Ebaugh's Creek	39.7120	76.5900	5	3	25	85
Deer Creek	39.7130	76.6000	15	8	15	97
Stone Run	39.7060	76.0670	15	8	45	88
Basin Run	39.6600	76.1450	14	15	35	85
Conowingo Creek	39.6930	76.1920	18	17	6	97
Conowingo Creek	39.7050	76.1930	16	15	15	85
Conowingo Creek	39.7050	76.1920	16	12	70	98
Basin Run	39.6540	76.0880	4	4	50	99
UT* to Susquehanna River	39.6380	76.1270	6	5	20	90
Stone Run	39.7040	76.1030	15	10	40	90
UT* to Stone Run	39.7010	76.0520	15	14	60	85
Conowingo Creek	39.6870	76.1930	15	16	15	62
Rock Run	39.6270	76.1180	17	16	50	85
Big Branch	39.7070	76.4830	14	8	20	90
South Stirrup Run	39.5970	76.4080	9	14	10	80
Mine Branch	39.6440	76.3580	13	9	30	85
Herring Run	39.5940	76.1360	15	17	10	70
Little Deer Creek	39.6630	76.4710	16	15	15	95
Little Deer Creek	39.6610	76.4470	16	12	40	99
Plumtree Branch	39.6800	76.5570	15	16	40	85
Jacks Hole	39.6830	76.4080	10	9	30	90
Big Branch	39.7170	76.4920	9	12	15	80
Broad Creek	39.6830	76.3640	13	8	40	85
Cabbage Run	39.6080	76.3480	9	11	40	95
Holland Branch	39.6470	76.2220	18	20	50	10
Deer Creek	39.6500	76.4990	15	15	40	95
UT* to Deer Creek	39.6310	76.3040	16	7	40	99
Broad Creek	39.6830	76.2800	13	8	95	99
UT* to Broad Creek	39.6530	76.3060	14	12	50	90
UT* to Deer Creek	39.6330	76.4810	9	10	10	80
Big Branch	39.6960	76.4650	14	15	20	95
Big Branch	39.6830	76.4600	18	18	15	99
Falling Branch	39.7150	76.4430	18	12	30	99
Broad Creek	39.6680	76.2950	6	10	40	75
Holland Branch	39.6290	76.2240	15	16	25	70

*** UT - Unnamed Tributary**

Stream Name	Latitude	Longitude	Shading (%)	Riparian Width (m)	Aesthetic Rating	Max. Depth (cm)	Gradient (%)
Ebaugh's Creek	39.7120	76.5900	80	50	11	88	3.5
Deer Creek	39.7130	76.6000	70	0	15	60	4.0
Stone Run	39.7060	76.0670	90	50	8	72	1.8
Basin Run	39.6600	76.1450	75	10	12	63	3.5
Conowingo Creek	39.6930	76.1920	49	50	15	68	3.0
Conowingo Creek	39.7050	76.1930	25	50	16	65	2.5
Conowingo Creek	39.7050	76.1920	25	50	16	66	2.0
Basin Run	39.6540	76.0880	50	0	16	80	1.5
UT* to Susquehanna River	39.6380	76.1270	80	28	7	21	2.0
Stone Run	39.7040	76.1030	75	0	14	140	1.0
UT* to Stone Run	39.7010	76.0520	80	0	14	50	1.8
Conowingo Creek	39.6870	76.1930	37	50	14	96	4.5
Rock Run	39.6270	76.1180	90	0	16	42	3.5
Big Branch	39.7070	76.4830	30	35	7	73	1.5
South Stirrup Run	39.5970	76.4080	94	50	16	52	1.5
Mine Branch	39.6440	76.3580	70	15	15	86	1.5
Herring Run	39.5940	76.1360	95	15	15	28	3.0
Little Deer Creek	39.6630	76.4710	80	0	15	110	1.2
Little Deer Creek	39.6610	76.4470	40	3	13	96	0.5
Plumtree Branch	39.6800	76.5570	95	50	19	48	2.5
Jacks Hole	39.6830	76.4080	98	5	13	42	0.7
Big Branch	39.7170	76.4920	90	20	9	105	1.0
Broad Creek	39.6830	76.3640	30	23	9	95	1.2
Cabbage Run	39.6080	76.3480	50	50	14	91	1.0
Holland Branch	39.6470	76.2220	90	50	16	22	3.5
Deer Creek	39.6500	76.4990	80	0	15	77	0.8
UT* to Deer Creek	39.6310	76.3040	40	13	12	33	1.5
Broad Creek	39.6830	76.2800	45	50	10	93	0.5
UT* to Broad Creek	39.6530	76.3060	95	35	15	35	1.8
UT* to Deer Creek	39.6330	76.4810	85	50	10	64	4.5
Big Branch	39.6960	76.4650	65	50	12	61	1.5
Big Branch	39.6830	76.4600	90	50	17	91	1.5
Falling Branch	39.7150	76.4430	35	0	7	74	1.5
Broad Creek	39.6680	76.2950	60	50	15	102	0.5
Holland Branch	39.6290	76.2240	95	30	11	85	2.8

*** UT - Unnamed Tributary**

Stream Name	Latitude	Longitude	Segment Length (m)	Woody Debris	Number of Rootwads
Ebaugh's Creek	39.7120	76.5900	70	0	0
Deer Creek	39.7130	76.6000	68	1	3
Stone Run	39.7060	76.0670	75	3	3
Basin Run	39.6600	76.1450	73	2	1
Conowingo Creek	39.6930	76.1920	73	1	0
Conowingo Creek	39.7050	76.1930	75	1	0
Conowingo Creek	39.7050	76.1920	75	1	1
Basin Run	39.6540	76.0880	43	2	0
UT* to Susquehanna River	39.6380	76.1270	68	0	0
Stone Run	39.7040	76.1030	66	5	3
UT* to Stone Run	39.7010	76.0520	72	0	5
Conowingo Creek	39.6870	76.1930	75	3	0
Rock Run	39.6270	76.1180	69	2	1
Big Branch	39.7070	76.4830	60	1	1
South Stirrup Run	39.5970	76.4080	62	1	3
Mine Branch	39.6440	76.3580	53	3	2
Herring Run	39.5940	76.1360	73	1	1
Little Deer Creek	39.6630	76.4710	68	1	1
Little Deer Creek	39.6610	76.4470	73	4	3
Plumtree Branch	39.6800	76.5570	74	0	1
Jacks Hole	39.6830	76.4080	74	4	3
Big Branch	39.7170	76.4920	49	0	1
Broad Creek	39.6830	76.3640	68	2	3
Cabbage Run	39.6080	76.3480	66	3	1
Holland Branch	39.6470	76.2220	65	0	0
Deer Creek	39.6500	76.4990	69	1	0
UT* to Deer Creek	39.6310	76.3040	73	0	0
Broad Creek	39.6830	76.2800	75	5	3
UT* to Broad Creek	39.6530	76.3060	60	4	1
UT* to Deer Creek	39.6330	76.4810	63	6	2
Big Branch	39.6960	76.4650	74	0	0
Big Branch	39.6830	76.4600	75	4	3
Falling Branch	39.7150	76.4430	69	3	0
Broad Creek	39.6680	76.2950	73	3	3
Holland Branch	39.6290	76.2240	70	4	1

*** UT - Unnamed Tributary**

ECOLOGY AND DISTRIBUTION OF FISH SPECIES COLLECTED IN THE LOWER SUSQUEHANNA BASIN

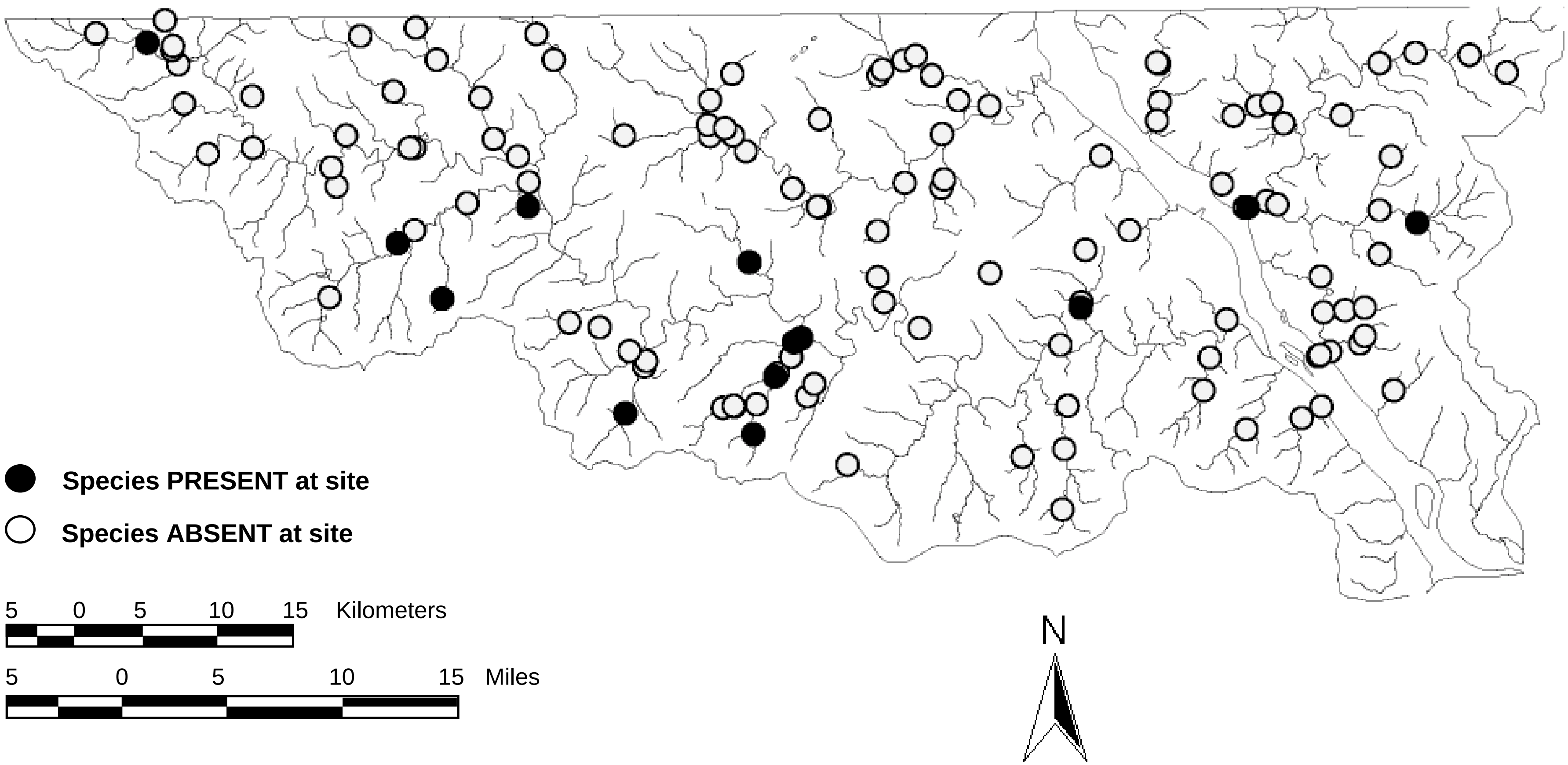
The species descriptions (Jenkins and Burkhead 1994, Rohde et al. 1994) and distributional maps which follow (Pages E5-E51) include those fish species collected during both random and non-random sampling in the Lower Susquehanna basin as part of the 1994 and 1997 MBSS.

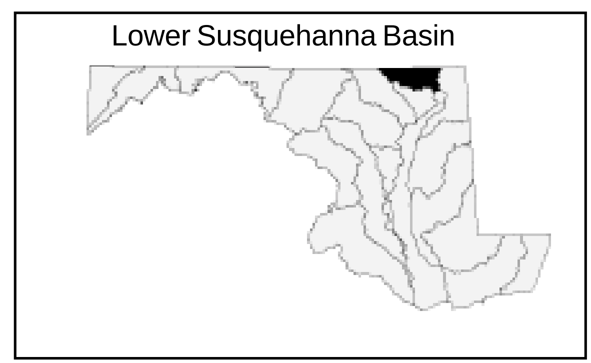
Common Name	*Family*	*Tolerance*	*Feeding Group*	*Page*	*Interesting Facts*
Sea lamprey	Lamprey	Moderate	Filter Feeder	E-5	Adults live in the ocean and use freshwater streams to spawn and grow to maturity (anadromous). This species was not found above Conowingo Dam.
American eel	Eel	Tolerant	Generalist	E-6	Although most of their life is spent in fresh water streams (up to 20 years or more), adults become silver in color and journey to the Sargasso sea to spawn (catadromous).
Gizzard shad	Herring	Moderate	Filter Feeder	E-7	Attempts have been made to stock this species as a forage base for game fish but they are only small enough to be taken by predators for a short time due to their rapid growth rate.
Blacknose dace	Minnow	Tolerant	Omnivore	E-8	This species is tolerant of a wide range of environmental conditions and pollutants. It is the most abundant fish in Maryland streams.
Bluntnose minnow	Minnow	Tolerant	Omnivore	E-9	As the name implies, this species is characterized by an extremely blunt snout.
Central stoneroller	Minnow	Moderate	Algivore	E-10	Because of its long intestine (up to 8 times its body length), this species is incredibly efficient at digesting detritus and algae.
Common carp	Minnow	Tolerant	Omnivore	E-11	This minnow is tolerant of many environmental conditions and can survive in highly degraded habitat.
Common shiner	Minnow	Moderate	Omnivore	E-12	This species often becomes more abundant when cold water streams become stressed by high temperatures.
Creek chub	Minnow	Tolerant	Generalist	E-13	Like other minnow species, this minnow doesn't have teeth around the jaw. However, it is quite capable of taking large prey items and readily strikes at lures intended for trout.
Cutlips minnow	Minnow	Moderate	Invertivore	E-14	This species is named for the presence of a bony lower jaw bordered on each side by a soft oval lobe.
Fallfish	Minnow	Moderate	Generalist	E-15	The male fallfish may build a large nest of gravel over 3 feet high to protect the eggs of its mate.

Common Name	*Family*	*Tolerance*	*Feeding Group*	*Page*	*Interesting Facts*
Golden shiner	Minnow	Tolerant	Omnivore	E-16	This species is a favorite food of largemouth bass. It has been transported throughout the United States as a result of bait bucket introductions.
Longnose dace	Minnow	Moderate	Omnivore	E-17	Its streamlined body shape and large fins allow this minnow to move around easily and remain stationary in fast currents.
River chub	Minnow	Moderate	Omnivore	E-18	During the breeding season, the male develops tubercles on its head and vigorously defends its nest from other males and egg-foraging predators.
Rosyface shiner	Minnow	Moderate	Invertivore	E-19	This species is an opportunistic feeder and preys on a variety of drifting and attached organisms.
Rosyside dace	Minnow	Intolerant	Invertivore	E-20	This minnow is considered to be sensitive to heavy siltation.
Satinfin shiner	Minnow	Moderate	Invertivore	E-21	This species is considered a good aquarium fish because of its active nature and ready acceptance of dried food.
Spotfin shiner	Minnow	Moderate	Invertivore	E-22	This species occurs in generally clear streams of moderate gradient and in the shallows of reservoirs and lakes. It is a warmwater species known to form small schools that are occasionally mixed with other minnows.
Spottail shiner	Minnow	Moderate	Omnivore	E-23	This species is found in a wide range of habitats, including tidal freshwater areas where it can be highly abundant.
Swallowtail shiner	Minnow	Moderate	Invertivore	E-24	This species seems to use both minnow and sunfish nests for spawning, unlike other minnows which only spawn on other minnow nests.
Creek chubsucker	Sucker	Moderate	Invertivore	E-25	This species lacks a lateral line and therefore is easily distinguishable from other suckers in Maryland.
Northern hogsucker	Sucker	Intolerant	Invertivore	E-26	Considered to be an aggressive feeder, this species has been known to overturn stones and gravel in search of food. Because of its highly camouflaged coloration, large schools of this species often go unnoticed by the casual observer.
Shorthead redhorse	Sucker	Moderate	Omnivore	E-27	Although thought to be the most widespread redhorse, this species is easily killed by pollution and excessive siltation. It received its name due to its rather small head that is markedly downsloped to the snout tip.
White sucker	Sucker	Tolerant	Omnivore	E-28	Large white suckers have been reported to reach 17 years of age and lengths of over 23 inches. This is the most widely distributed sucker species in Maryland.

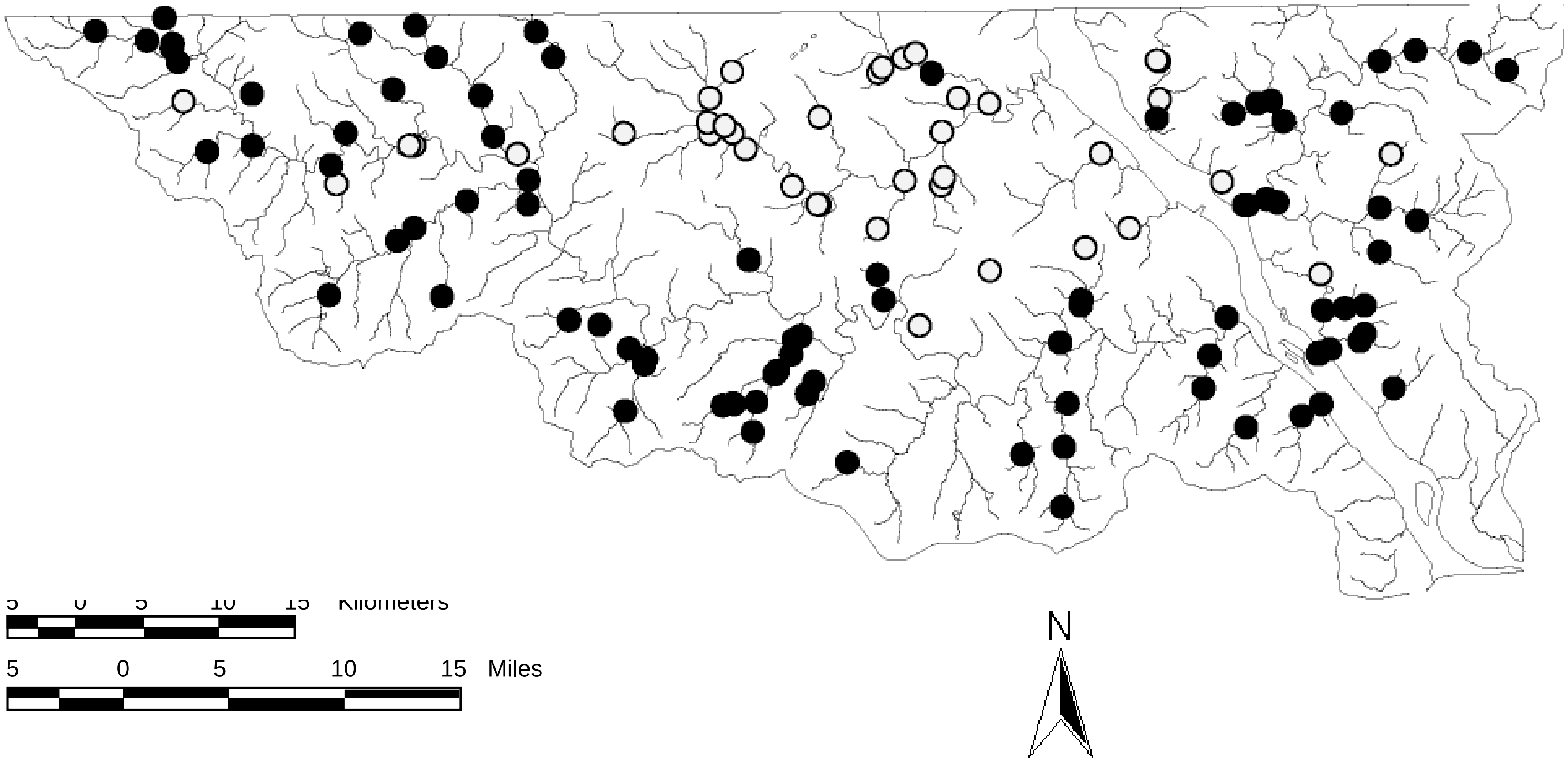
Common Name	*Family*	*Tolerance*	*Feeding Group*	*Page*	*Interesting Facts*
Brown bullhead	Catfish	Tolerant	Omnivore	E-29	Although considered native to Maryland, this species has been widely introduced throughout the United States to provide fishing opportunities.
Channel catfish	Catfish	Moderate	Omnivore	E-30	This is probably the most familiar and popular catfish in North America. In addition to its popularity with anglers, it a prized food fish that is widely raised in hatcheries.
Margined madtom	Catfish	Moderate	Invertivore	E-31	This is a highly nocturnal species which requires hiding places to thrive. The spines of margined madtoms are venomous and can inflict considerable pain if handled incorrectly.
Yellow bullhead	Catfish	Tolerant	Omnivore	E-32	Although bullheads are considered bottom feeders, when given the opportunity they are quite capable of catching and eating fish such as minnows and sunfish.
Brook trout	Trout	Intolerant	Generalist	E-33	Commonly found in cold headwater streams, this species is the only trout native to Maryland.
Brown trout	Trout	Moderate	Top Predator	E-34	This European species was widely introduced prior to 1900 and has contributed to the widespread decline of brook trout in the eastern United States.
Rainbow trout	Trout	Moderate	Top Predator	E-35	Although ranked among the top five sought after gamefish in North America, hatchery-reared fish are not considered desirable by many fishing purists.
Banded killifish	Killifish	Moderate	Invertivore	E-36	As a result of its hardy nature and general abundance this species is often used as live bait.
Mummichog	Killifish	Moderate	Invertivore	E-37	This species is more commonly found in estuaries and can tolerate salinities up to 32 parts/thousand.
Mottled sculpin	Sculpin	Moderate	Insectivore	E-38	This species is primarily an insectivore and does the majority of its feeding nocturnally. It is the second most abundant stream fish in Maryland.
White perch	Temperate bass	Moderate	Invertivore	E-39	This species spawns from late March through May, migrating from the lower portions of the Chesapeake Bay upstream to freshwater (semi-anadromous). It is abundant in tidal waters of the Susquehanna River.
Bluegill	Sunfish	Tolerant	Invertivore	E-40	This species has been widely introduced throughout the United States, and has flourished as a result of its tolerance to a variety of conditions.
Green sunfish	Sunfish	Tolerant	Generalist	E-41	This species is intolerant of low pH streams, but tolerant of many other types of stress. The lowest pH stream site in the basin where this sunfish was collected at was 7.1.

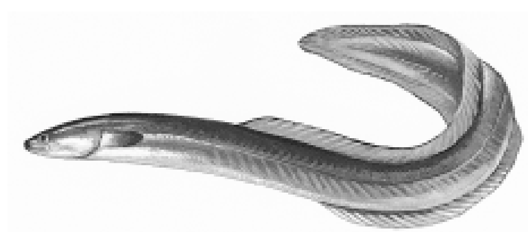
Common Name	Family	Tolerance	Feeding Group	Page	Interesting Facts
Largemouth bass	Sunfish	Moderate	Top Predator	E-42	This species is considered the most popular gamefish in the United States and has been known to reach weights of over 20 pounds.
Pumpkinseed	Sunfish	Moderate	Invertivore	E-43	This sunfish is tolerant of darkly-stained acidic waters and is a regular visitor to brackish waters.
Redbreast sunfish	Sunfish	Moderate	Generalist	E-44	Often found with smallmouth bass and other “cool water” species, this sunfish has been found in water warmer than 100º F.
Rock bass	Sunfish	Moderate	Generalist	E-45	This big-mouthed sunfish is an ambush predator that feeds on a wide variety of minnows and aquatic insects.
Smallmouth bass	Sunfish	Moderate	Top Predator	E-46	One reason for this species’ popularity as a gamefish is its aggressive nature and frequent aerial acrobatics when hooked on light tackle.
Logperch	Perch	Moderate	Insectivore	E-47	This species is rare in Maryland and restricted to only two basins.
Banded darter	Perch	Intolerant	Insectivore	E-48	This inconspicuous species is not native to Maryland.
Shield darter	Perch	Intolerant	Insectivore	E-49	Of the genus *Etheostoma*, the greenside darter is the largest and only darter that features a blunt snout.
Tessellated darter	Perch	Moderate	Invertivore	E-50	The male tessellated darter has a curious behavior of frequently caring for nests containing eggs that it did not fertilize.
Yellow Perch	Perch	Moderate	Generalist	E-51	The yellow perch population in Chesapeake Bay is unique because it winters in areas of moderate salinity; all other populations spend their entire life cycle in freshwater.

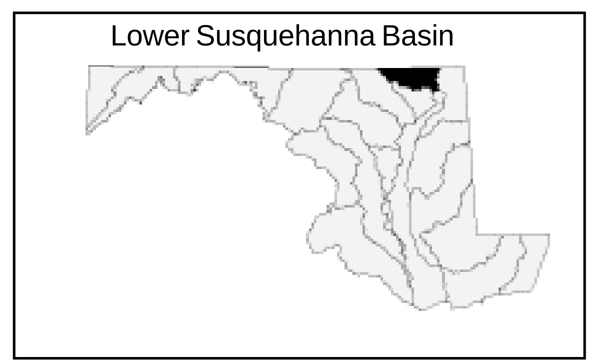




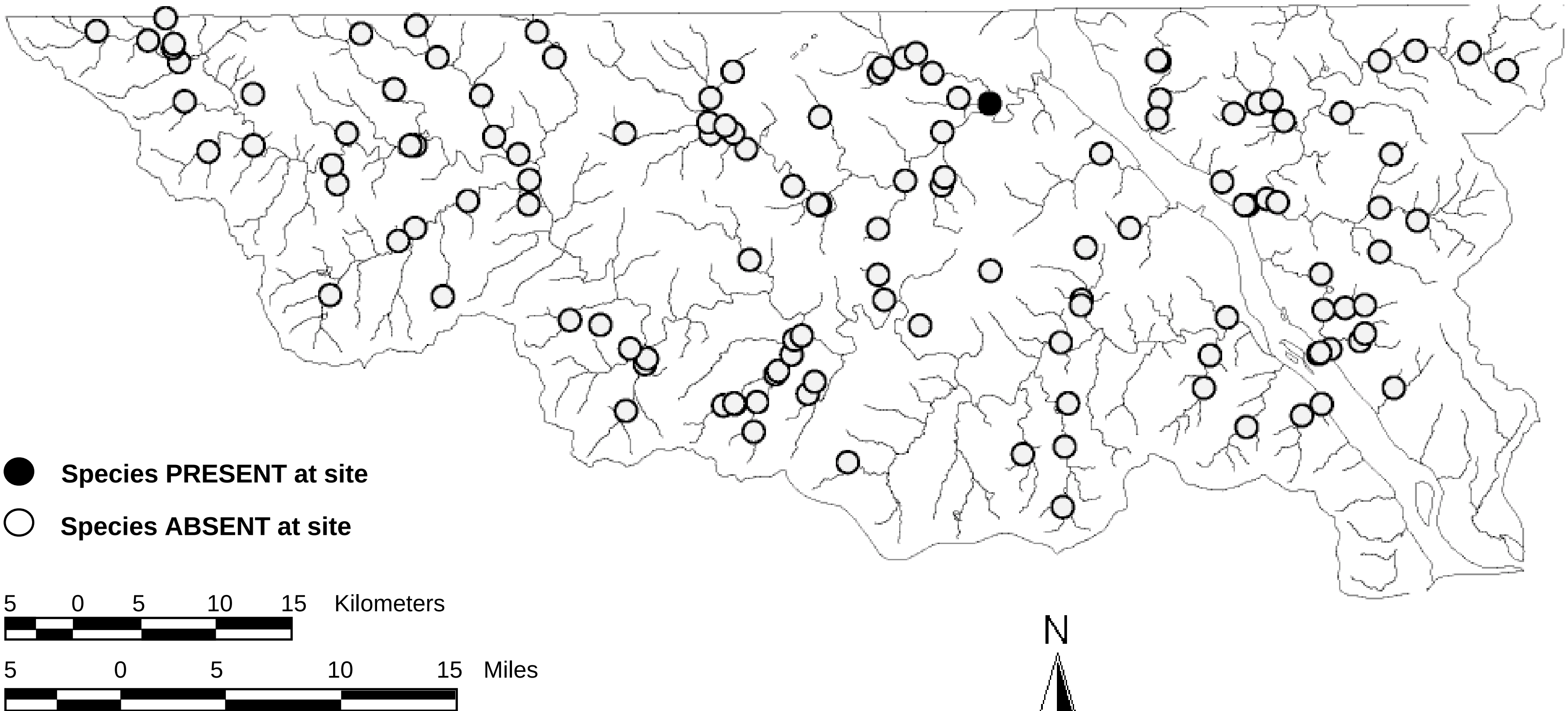
Distribution of sea lamprey in the Lower Susquehanna basin, 1994 and 1997.

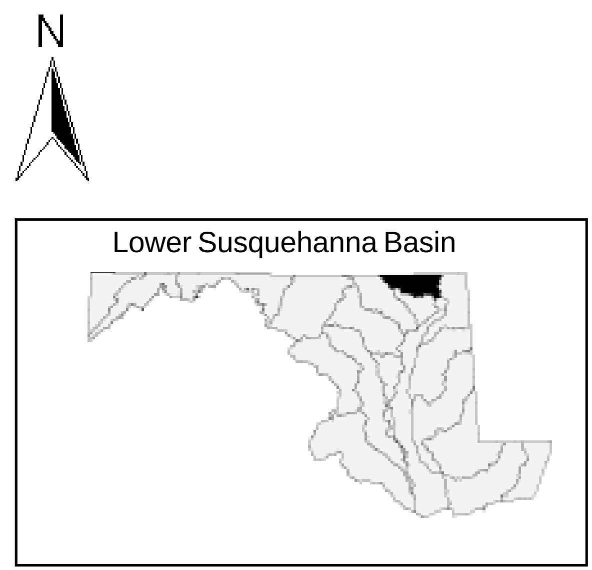


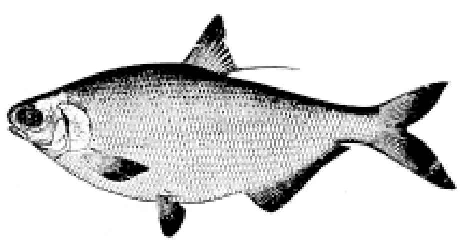




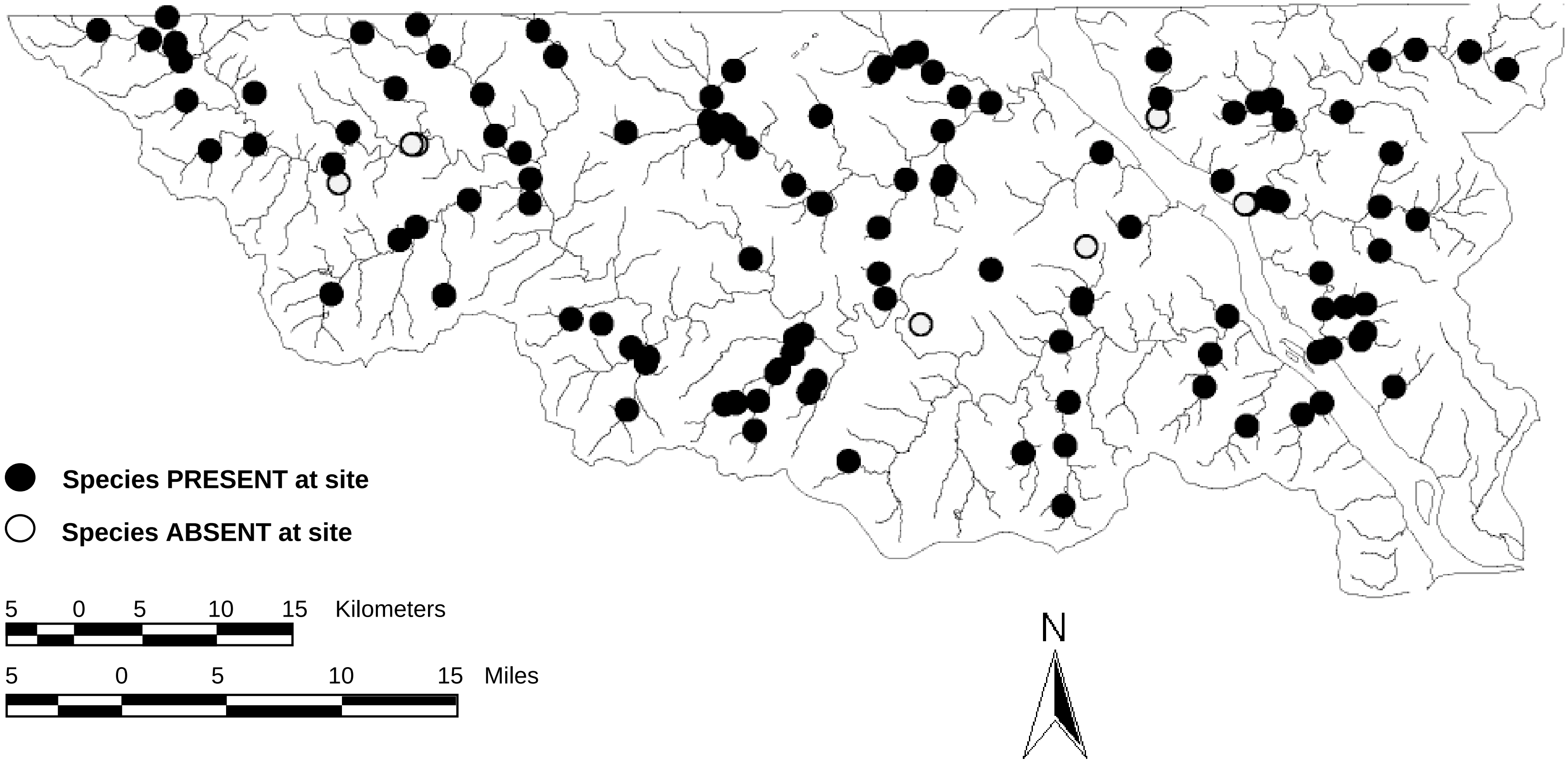
Distribution of American eel in the Lower Susquehanna basin, 1994 and 1997.

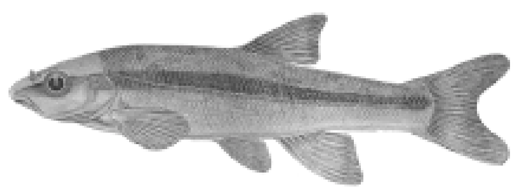


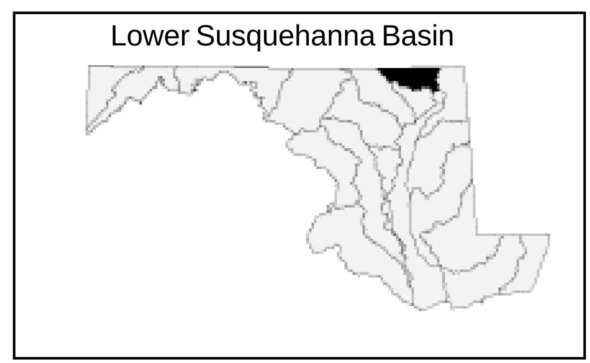




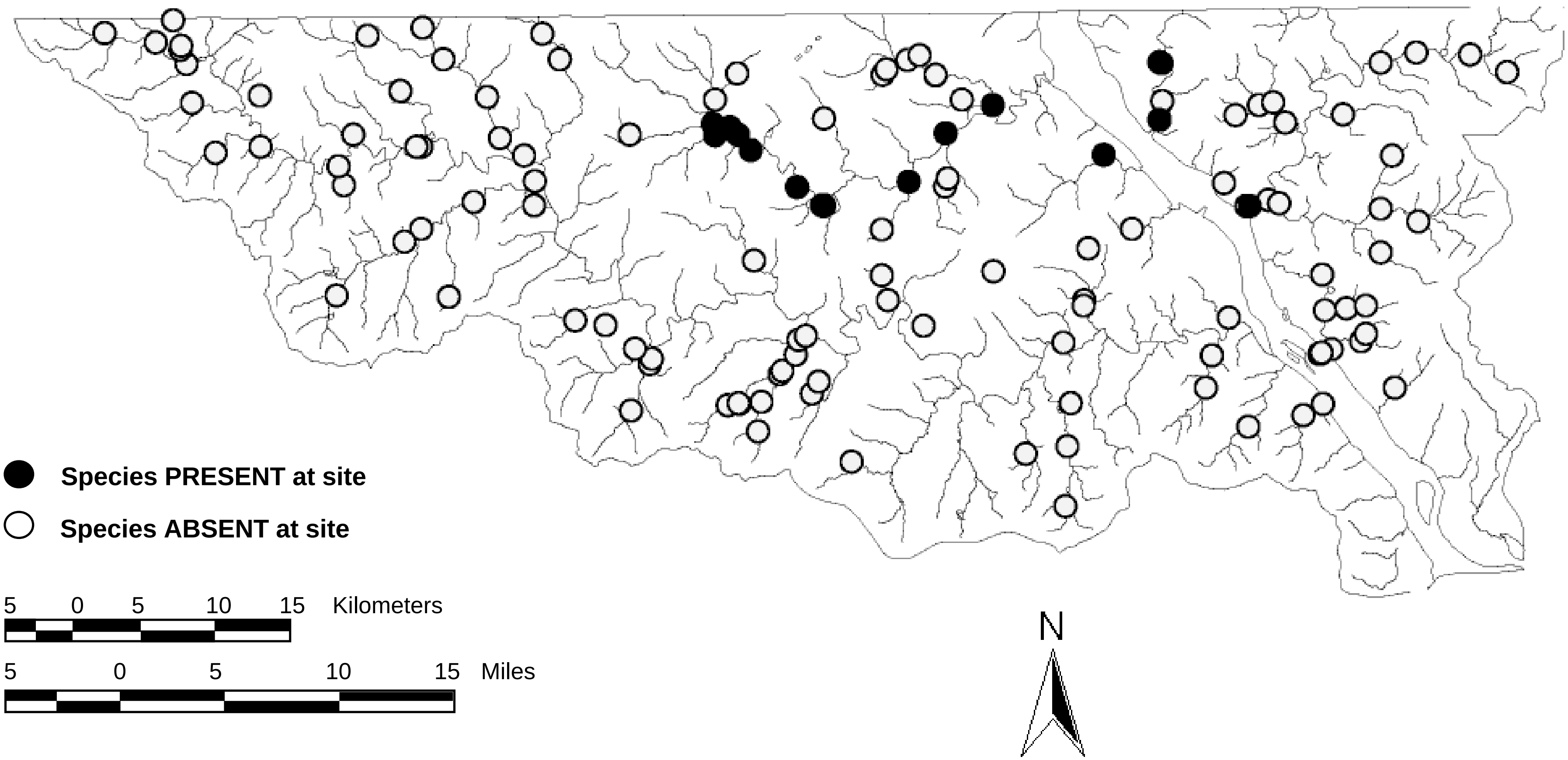
Distribution of gizzard shad in the Lower Susquehanna basin, 1994 and 1997.

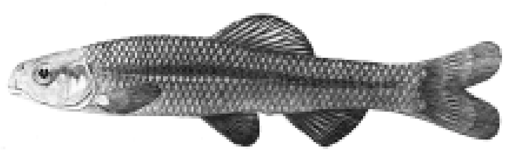


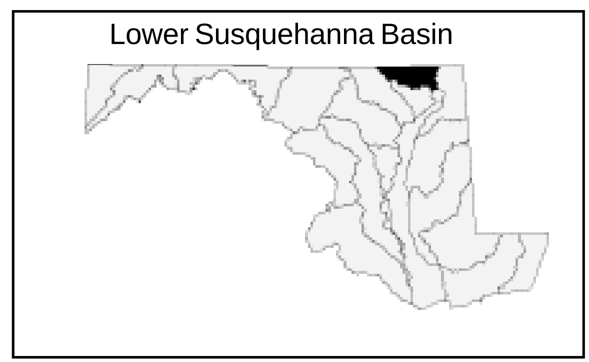




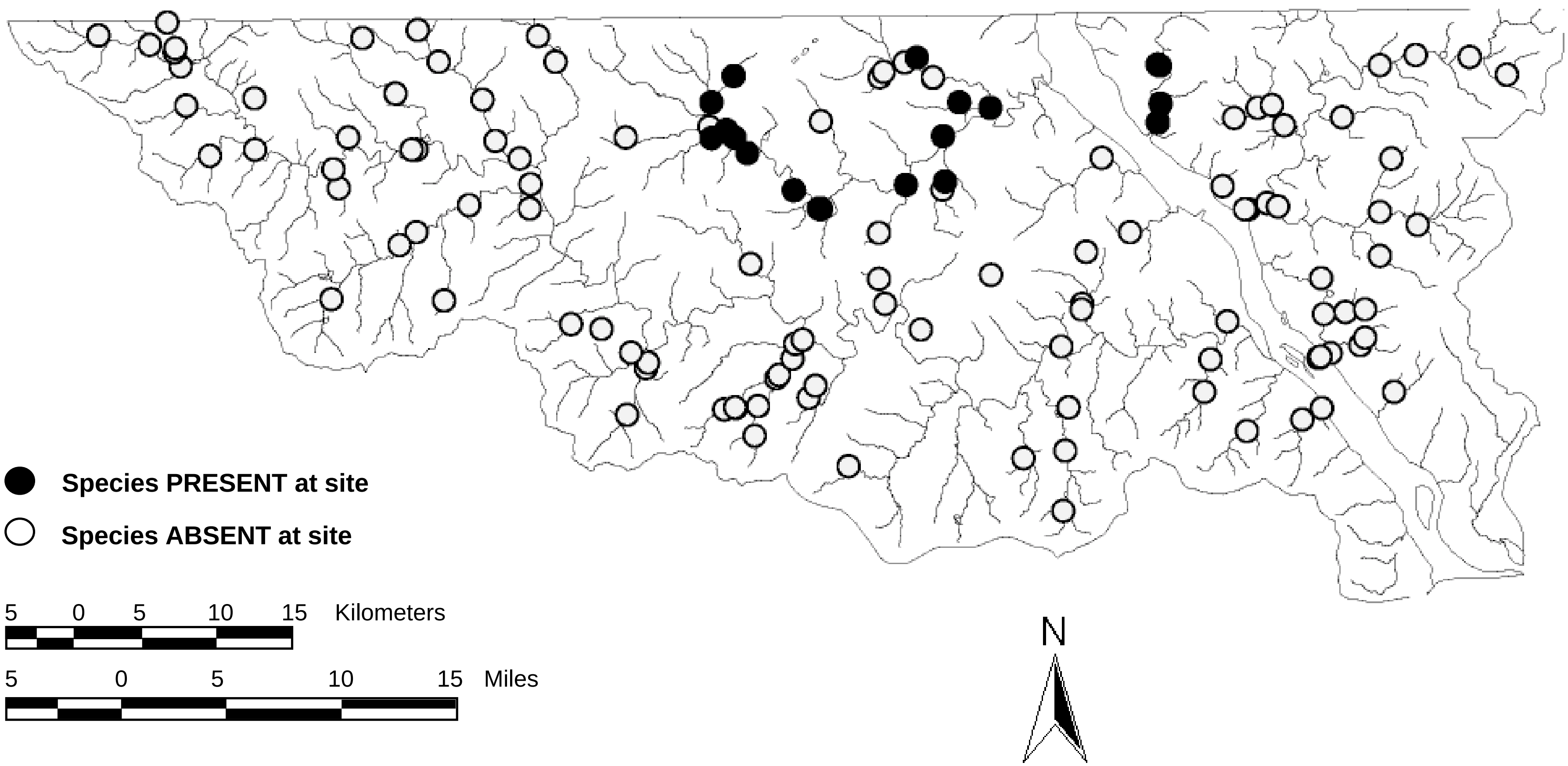
Distribution of blacknose dace in the Lower Susquehanna basin, 1994 and 1997.

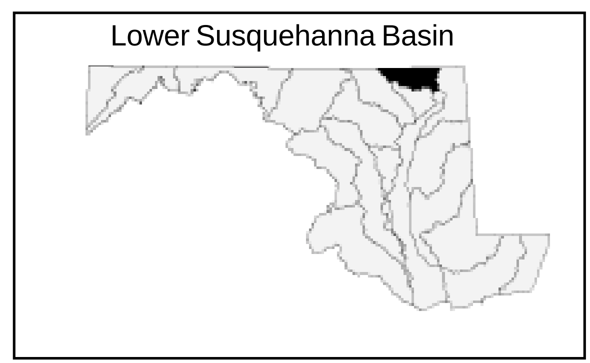




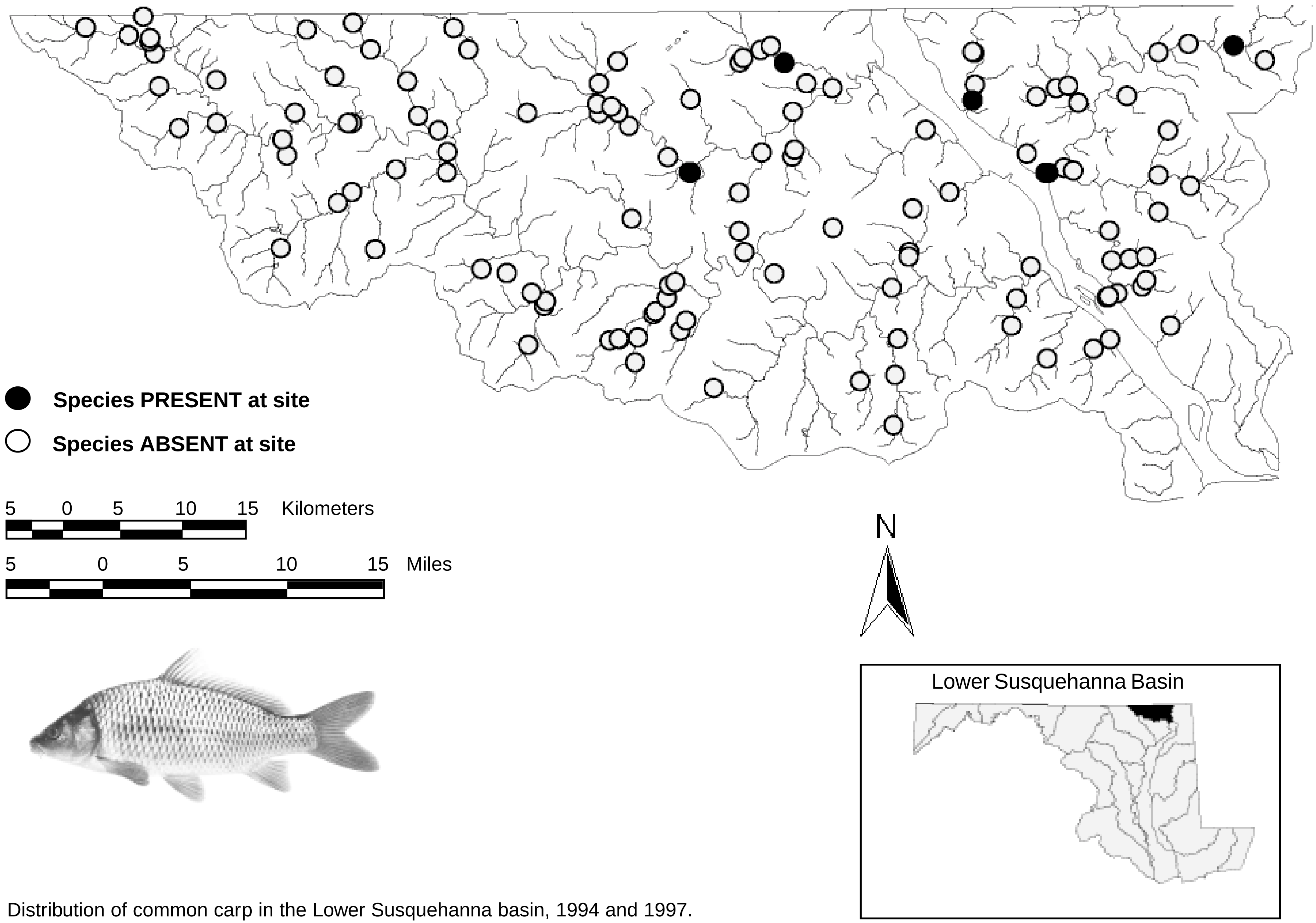


Distribution of bluntnose minnow in the Lower Susquehanna basin, 1994 and 1997.

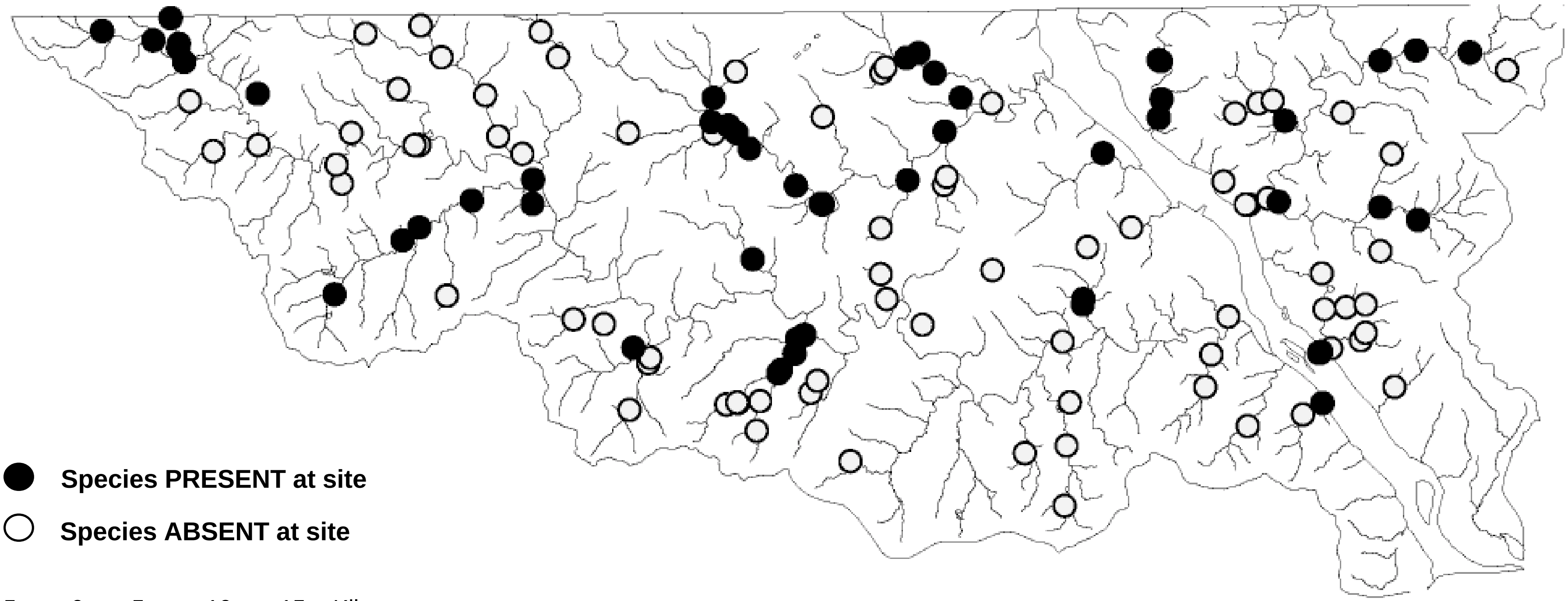




Distribution of Central stoneroller in the Lower Susquehanna basin, 1994 and 1997.



Distribution of common carp in the Lower Susquehanna basin, 1994 and 1997.

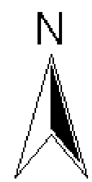


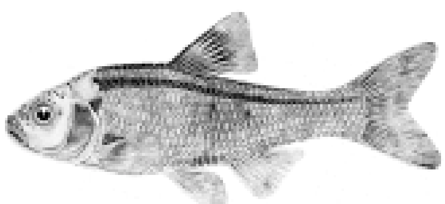
Species PRESENT at site

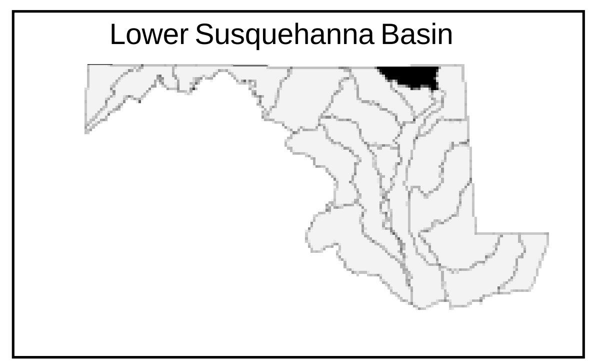
Species ABSENT at site

5 0 5 10 15 Kilometers

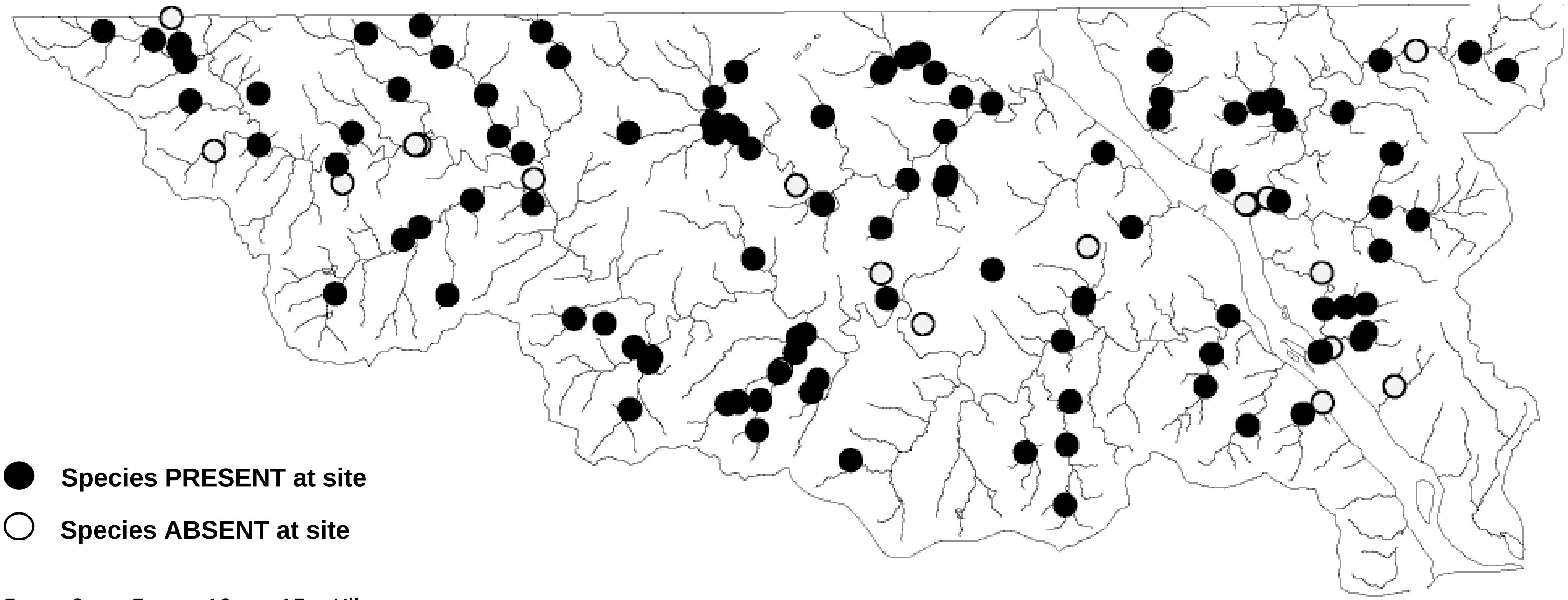
5 0 5 10 15 Miles







Distribution of common shiner in the Lower Susquehanna basin, 1994 and 1997.



Species PRESENT at site

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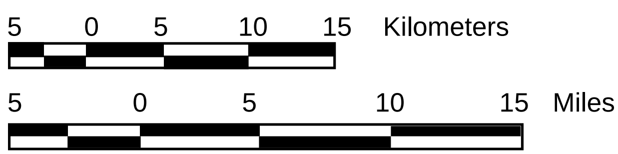
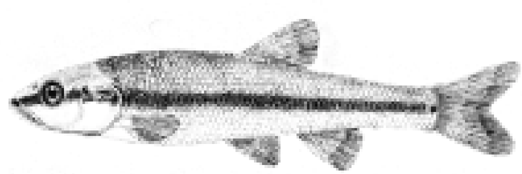
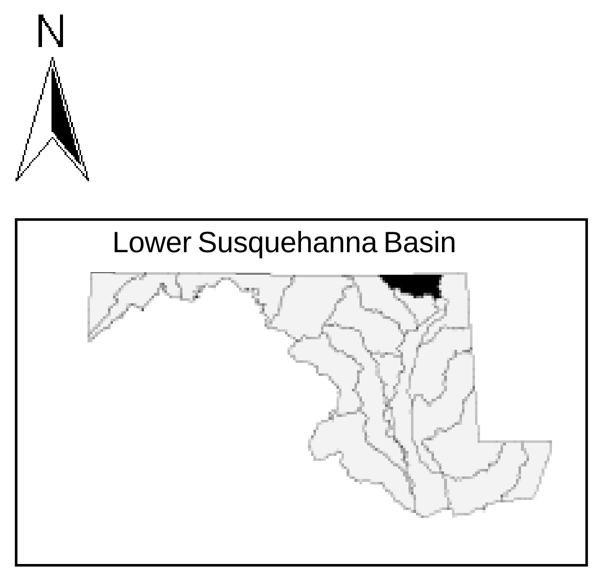
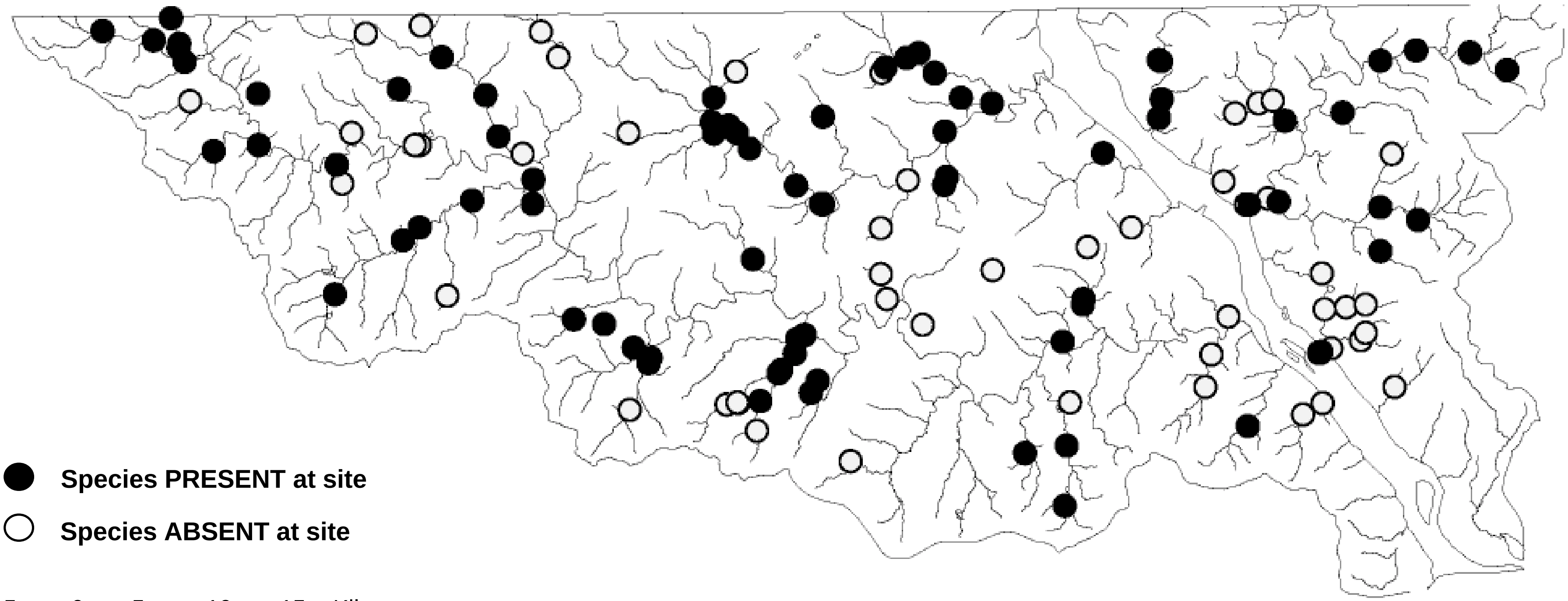






Distribution of creek chub in the Lower Susquehanna basin, 1994 and 1997.



Species PRESENT at site

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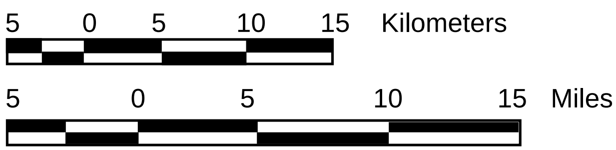
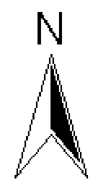
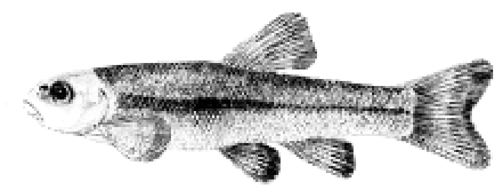
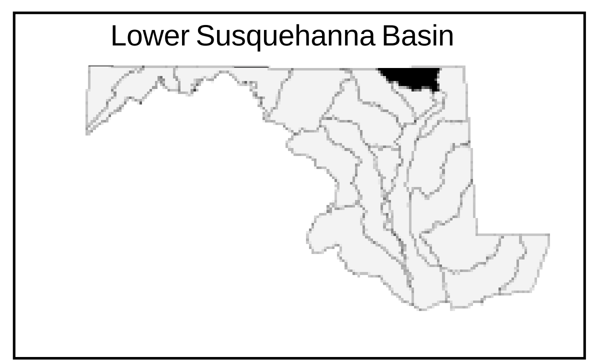
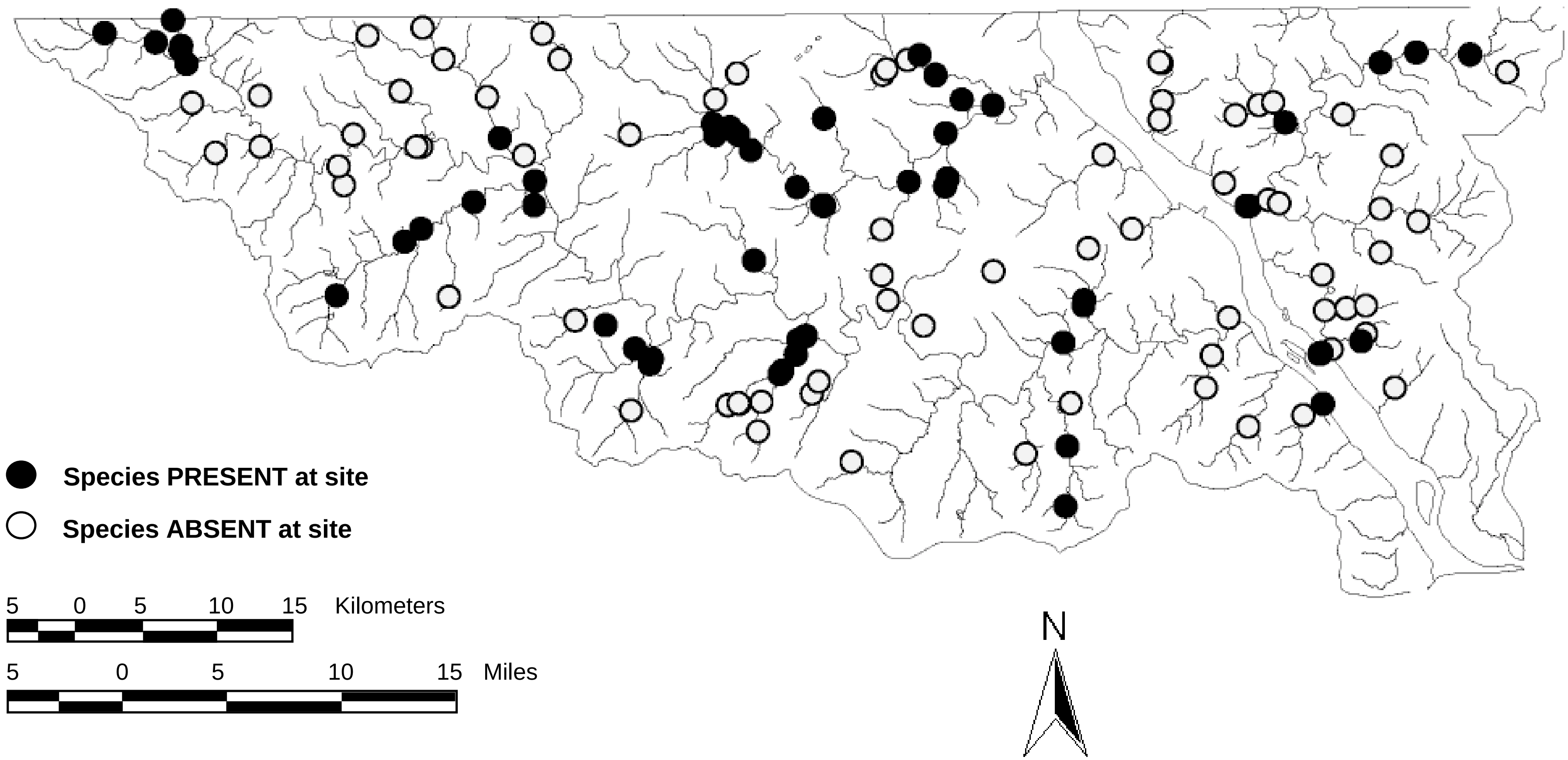


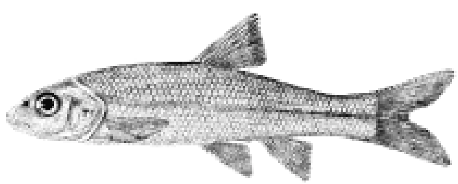


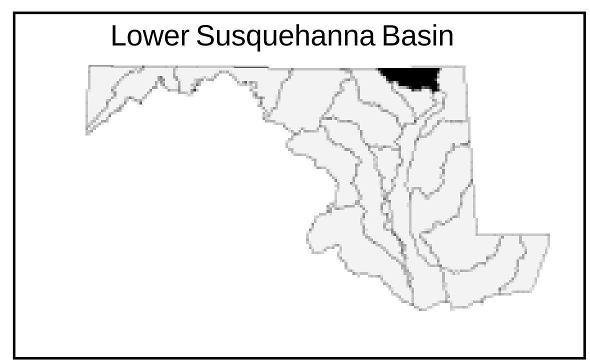




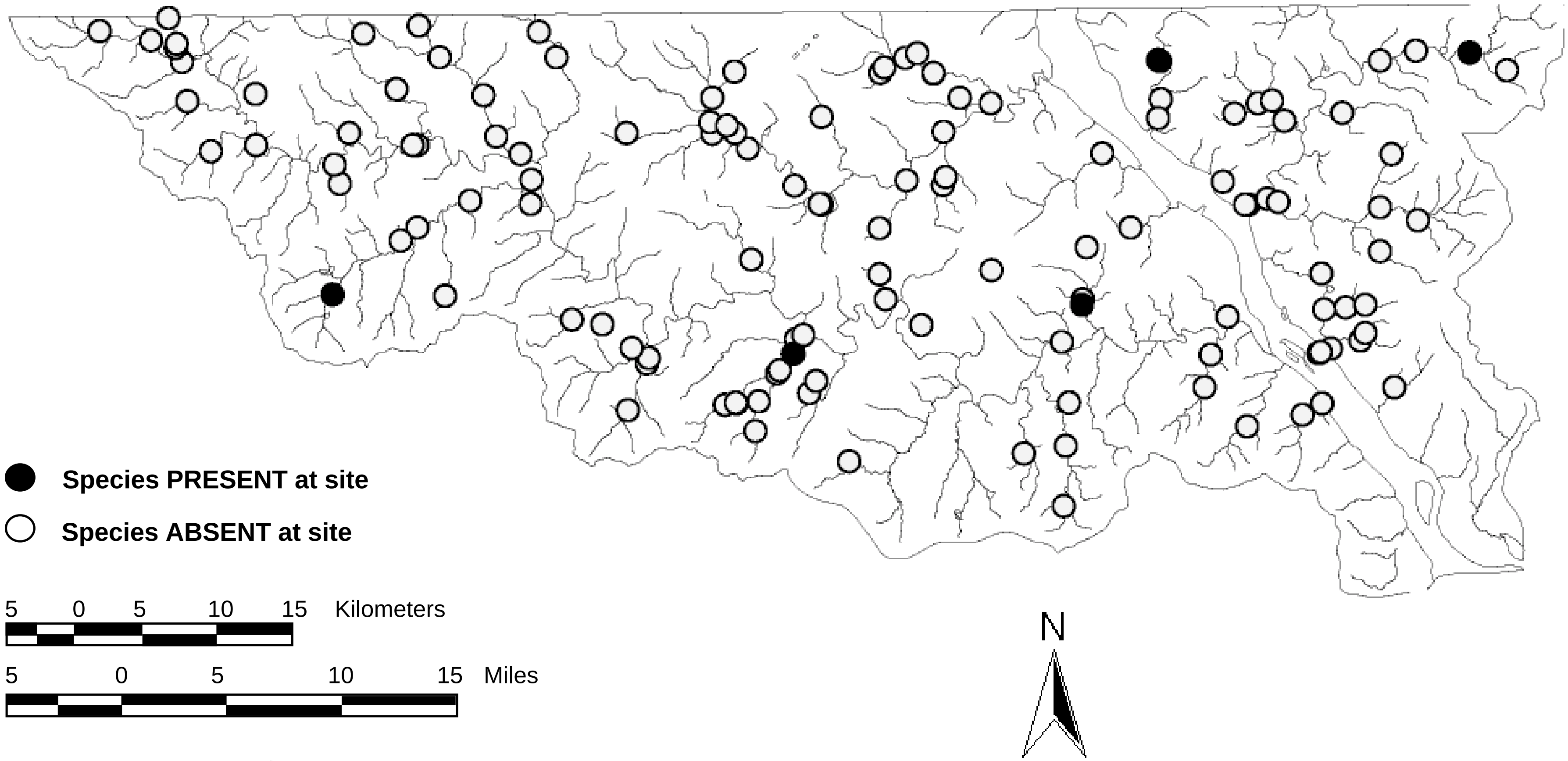
Distribution of cutlips minnow in the Lower Susquehanna basin, 1994 and 1997.

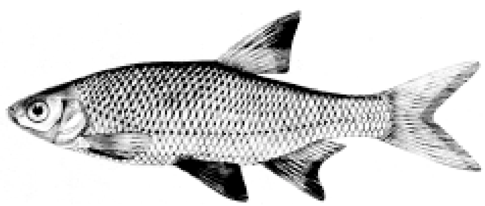


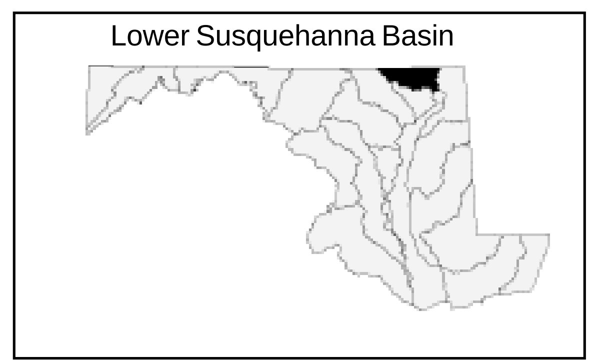




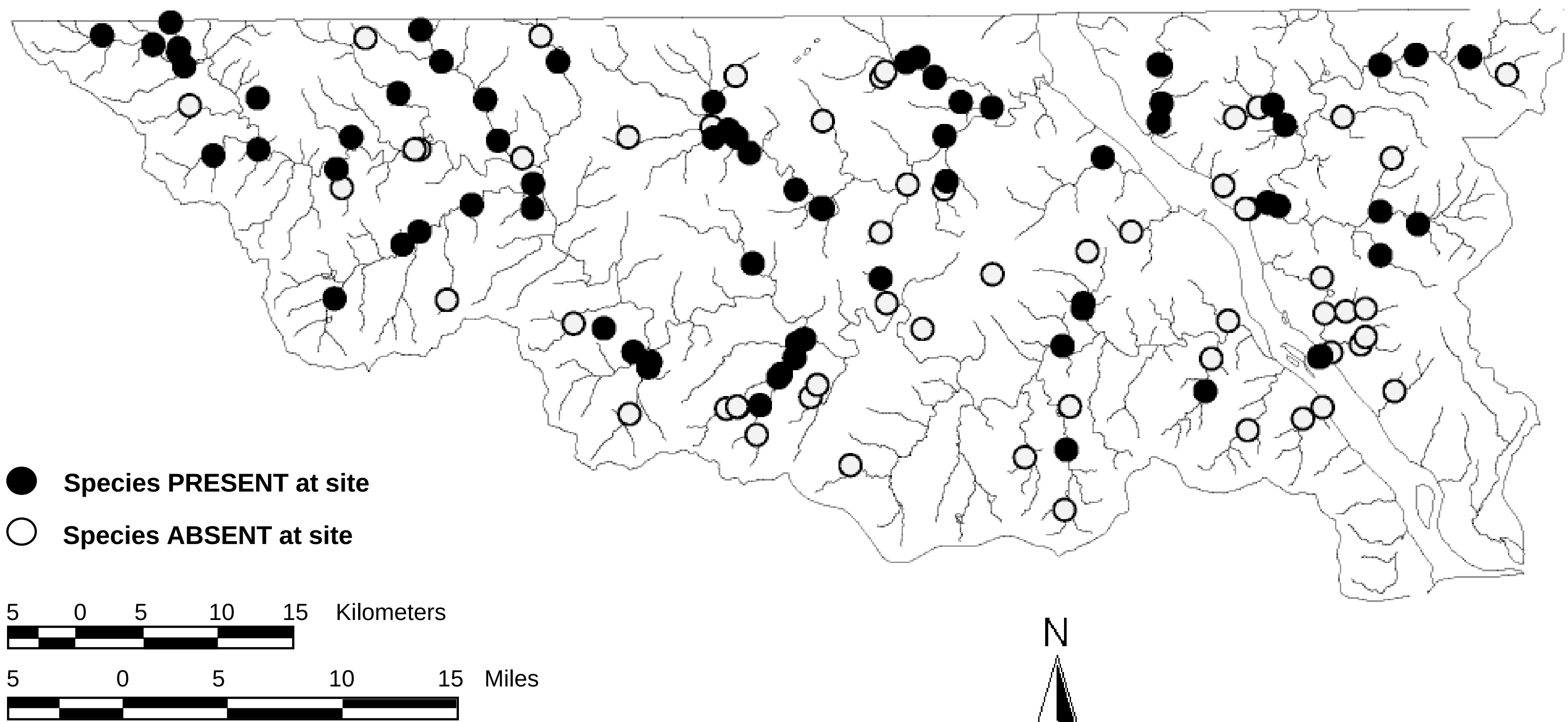
Distribution of fallfish in the Lower Susquehanna basin, 1994 and 1997.

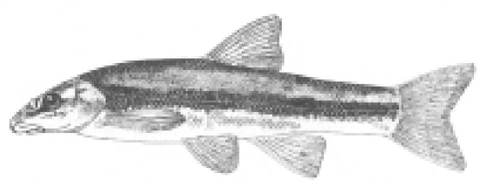


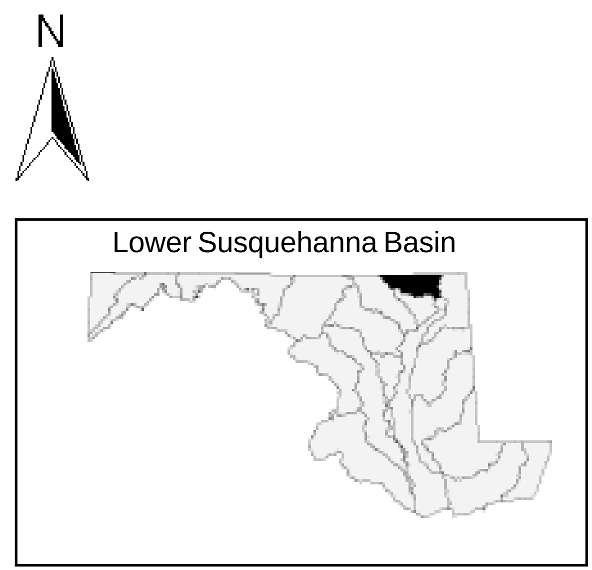




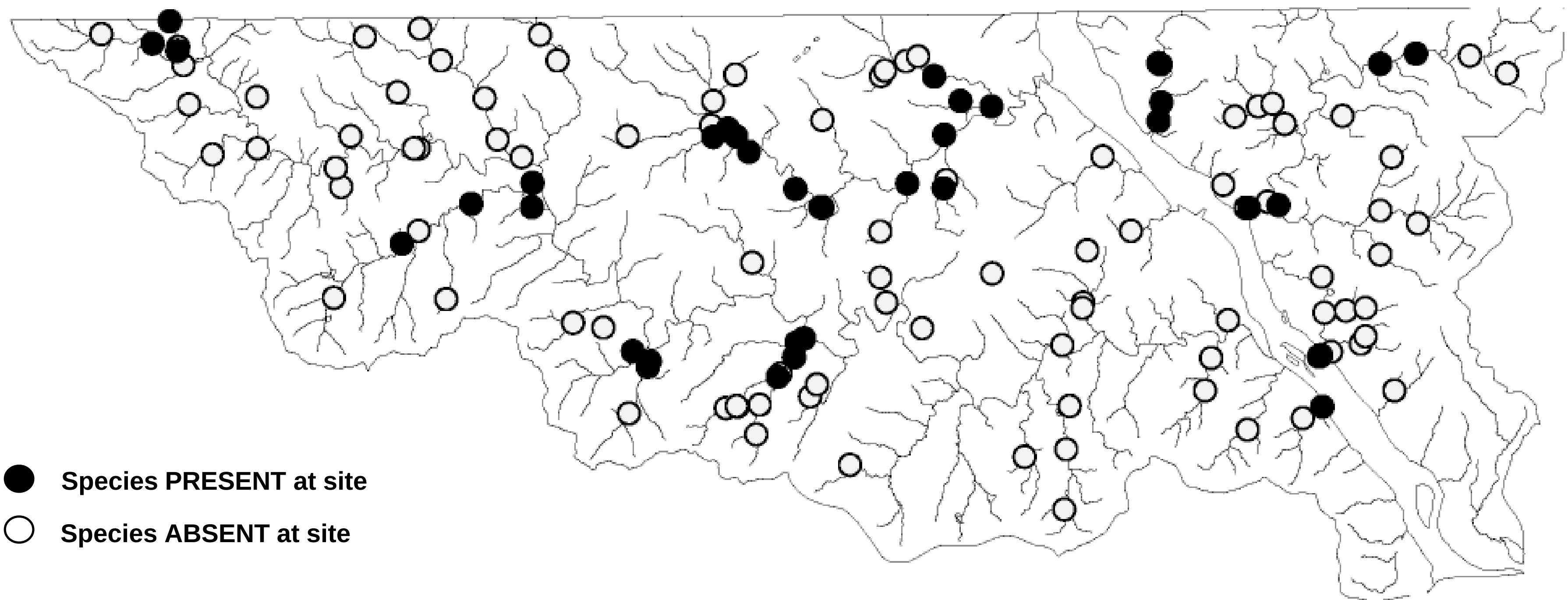
Distribution of golden shiner in the Lower Susquehanna basin, 1994 and 1997.







Distribution of longnose dace in the Lower Susquehanna basin, 1994 and 1997.

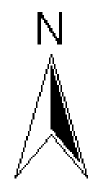


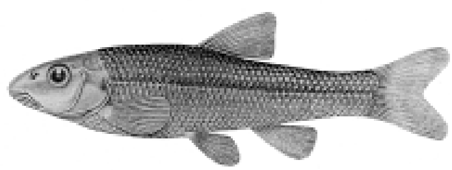
Species PRESENT at site

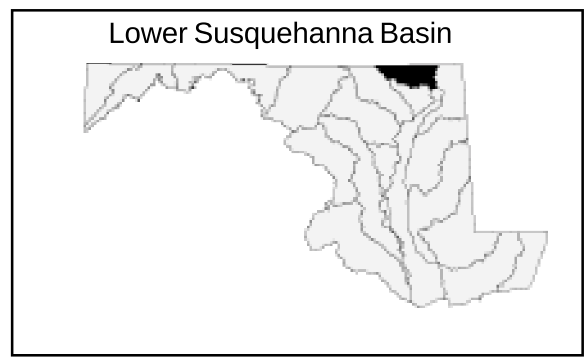
Species ABSENT at site

5 0 5 10 15 Kilometers

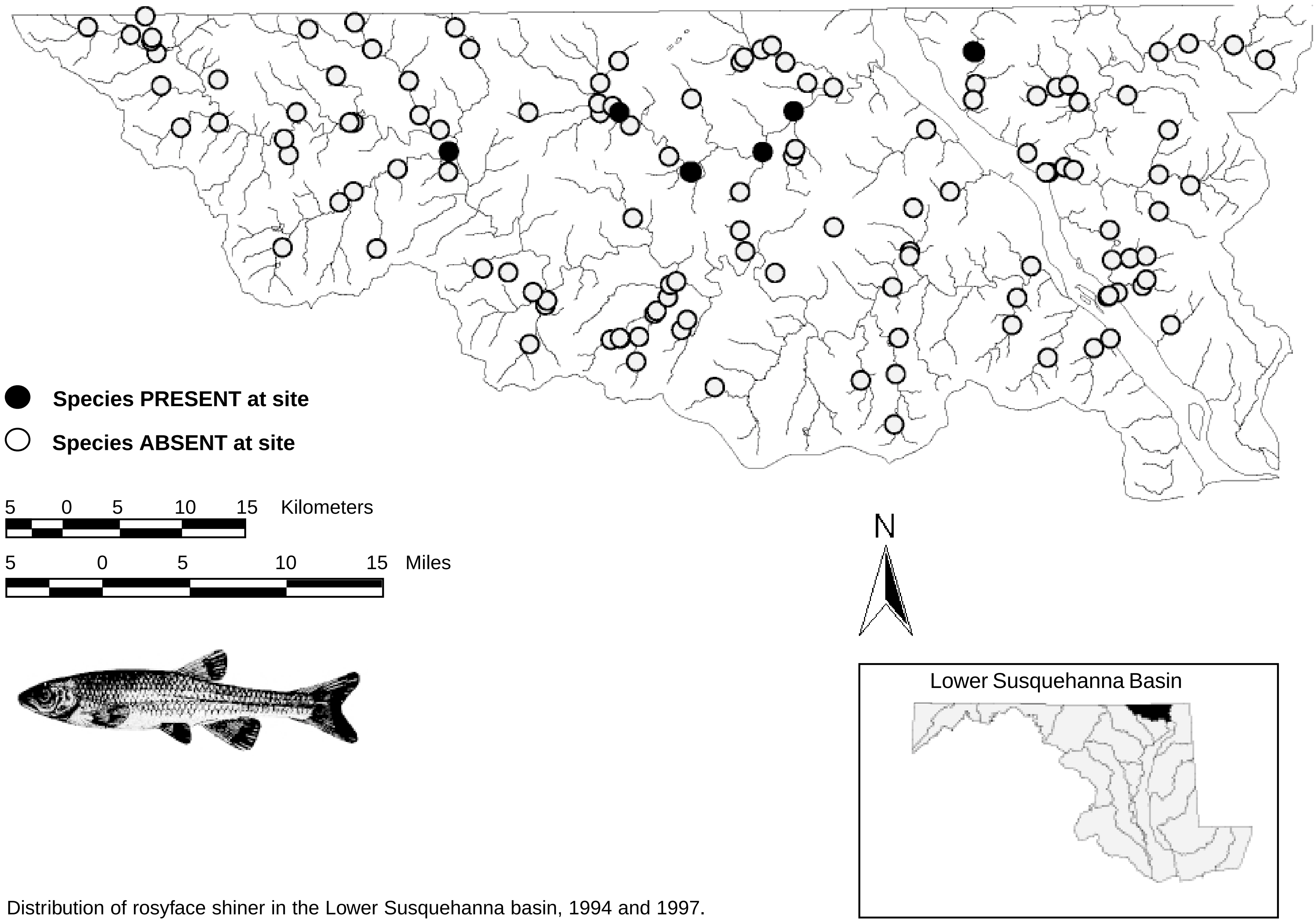
5 0 5 10 15 Miles



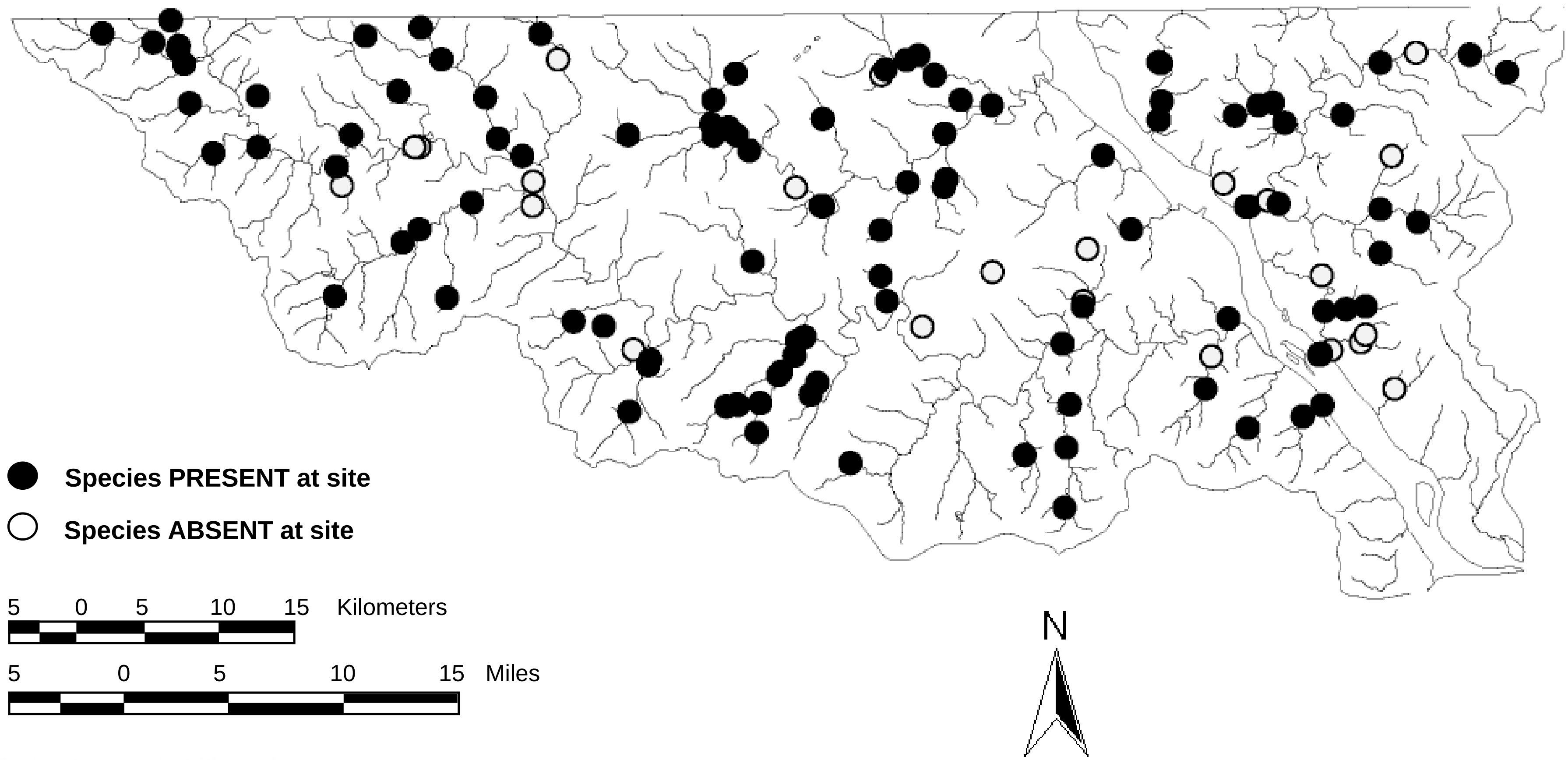


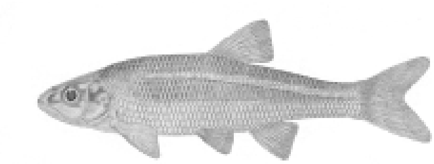


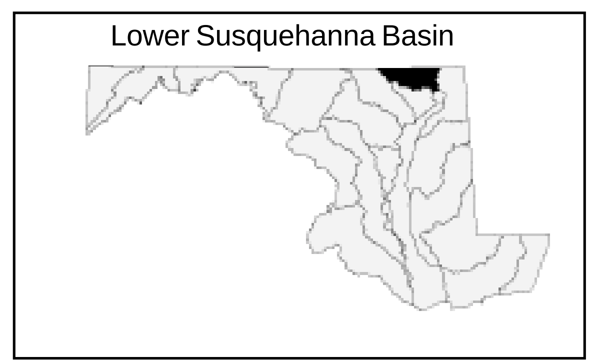
Distribution of river chub in the Lower Susquehanna basin, 1994 and 1997.



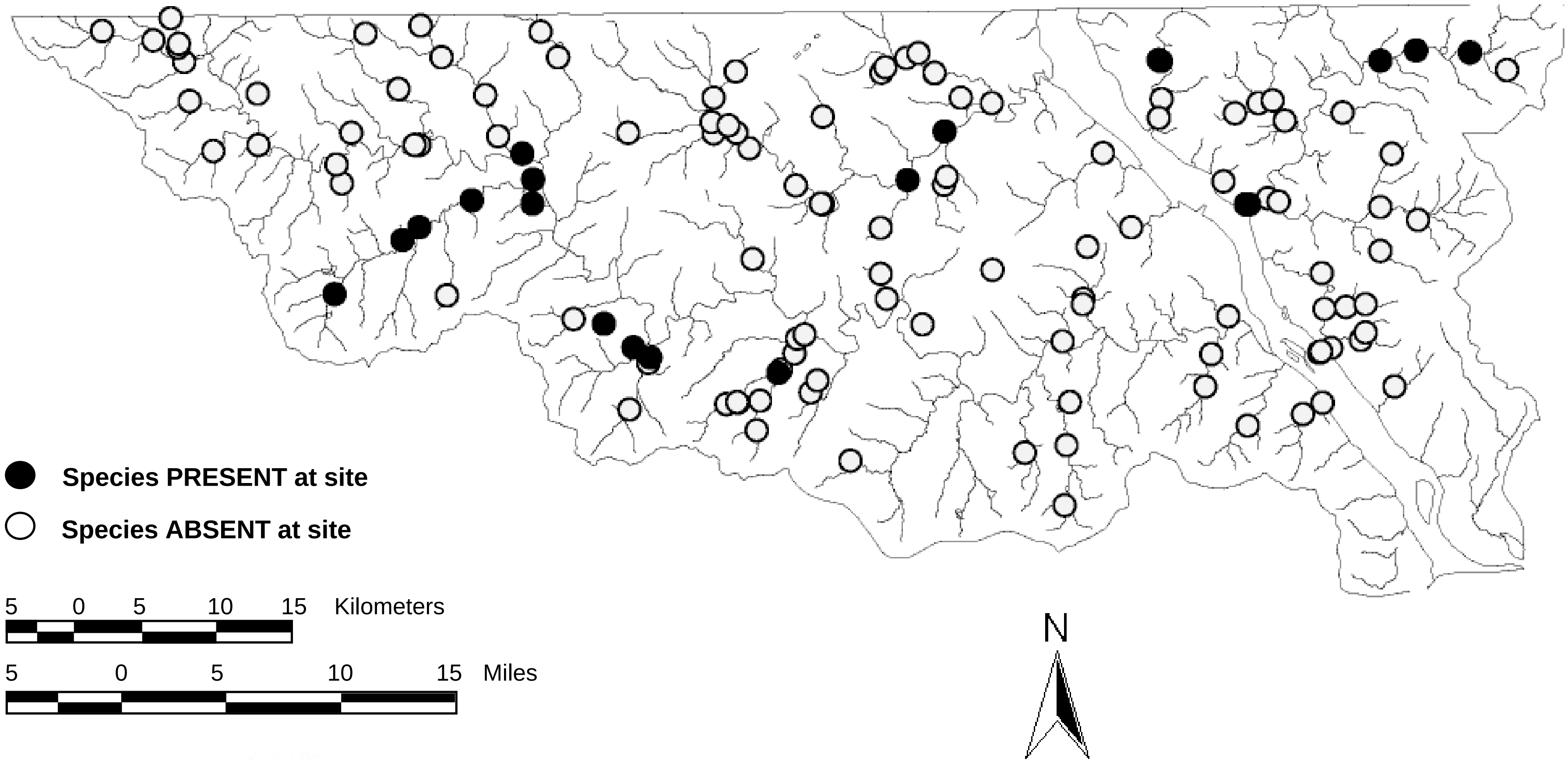
Distribution of rosyface shiner in the Lower Susquehanna basin, 1994 and 1997.

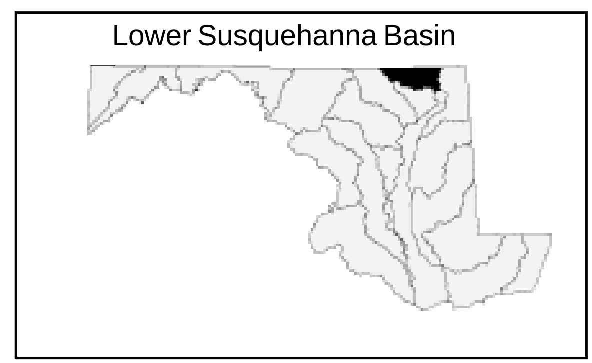




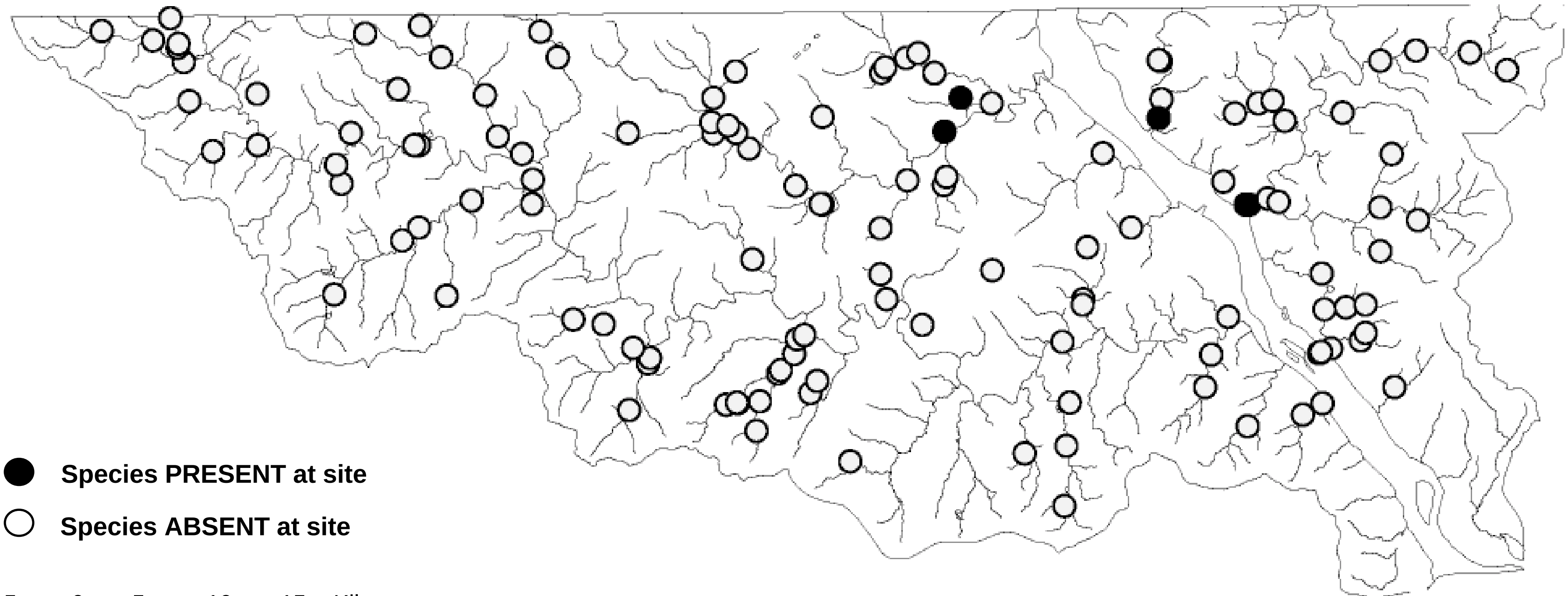


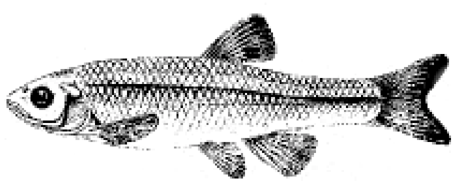
Distribution of rosyside dace in the Lower Susquehanna basin, 1994 and 1997.

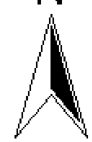


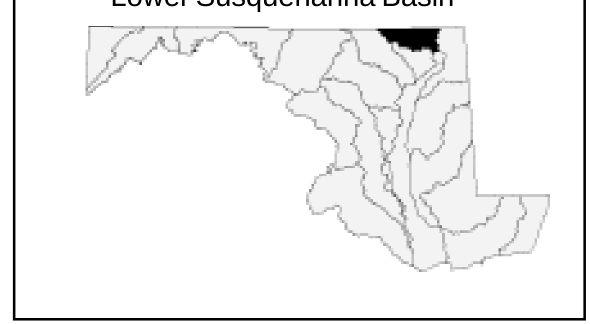


Distribution of satinfin shiner in the Lower Susquehanna basin, 1994 and 1997.

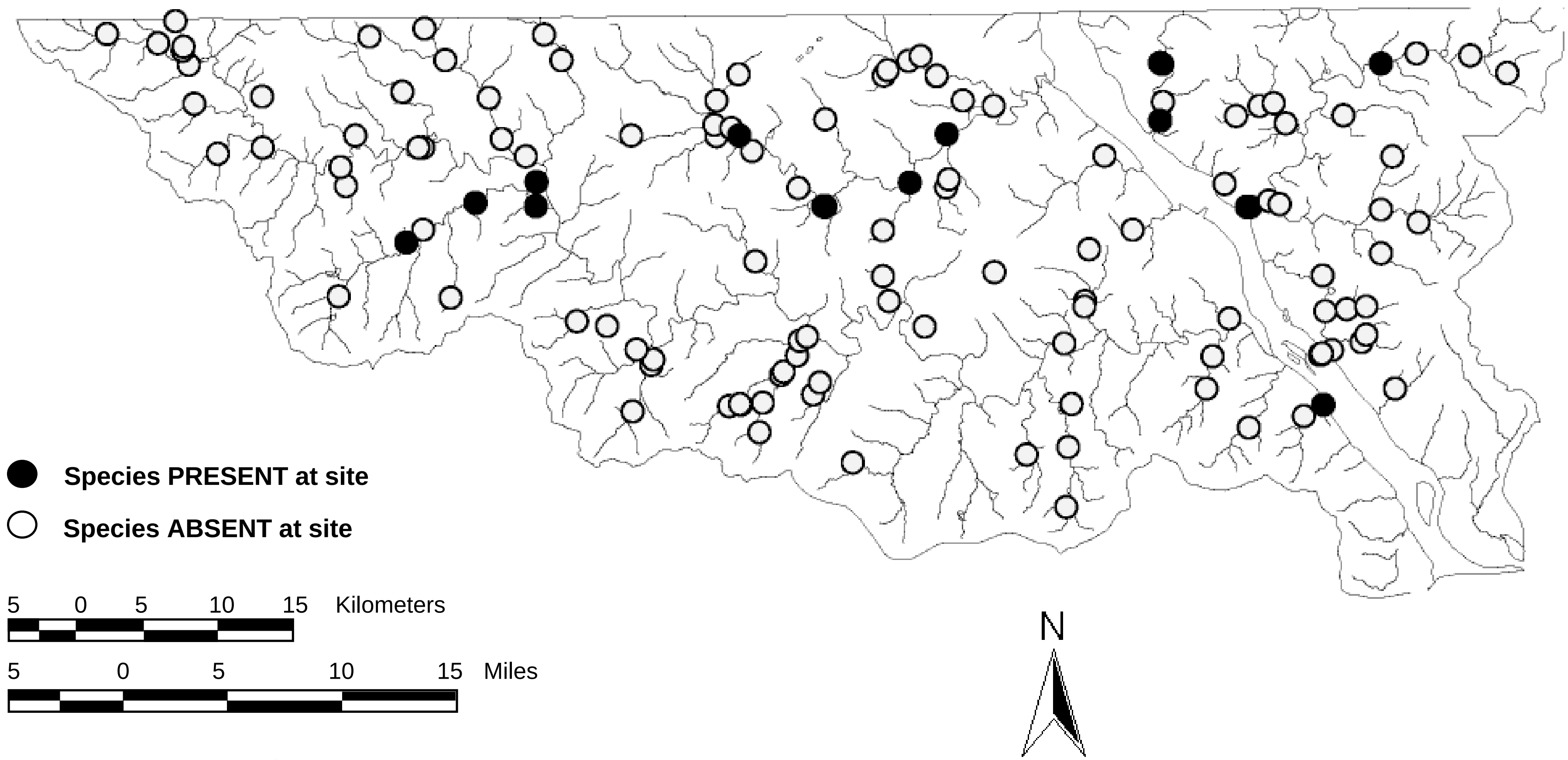


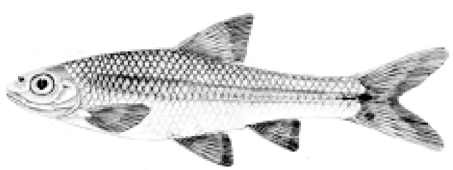


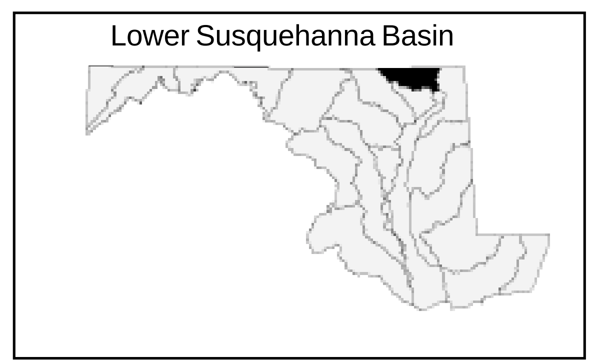




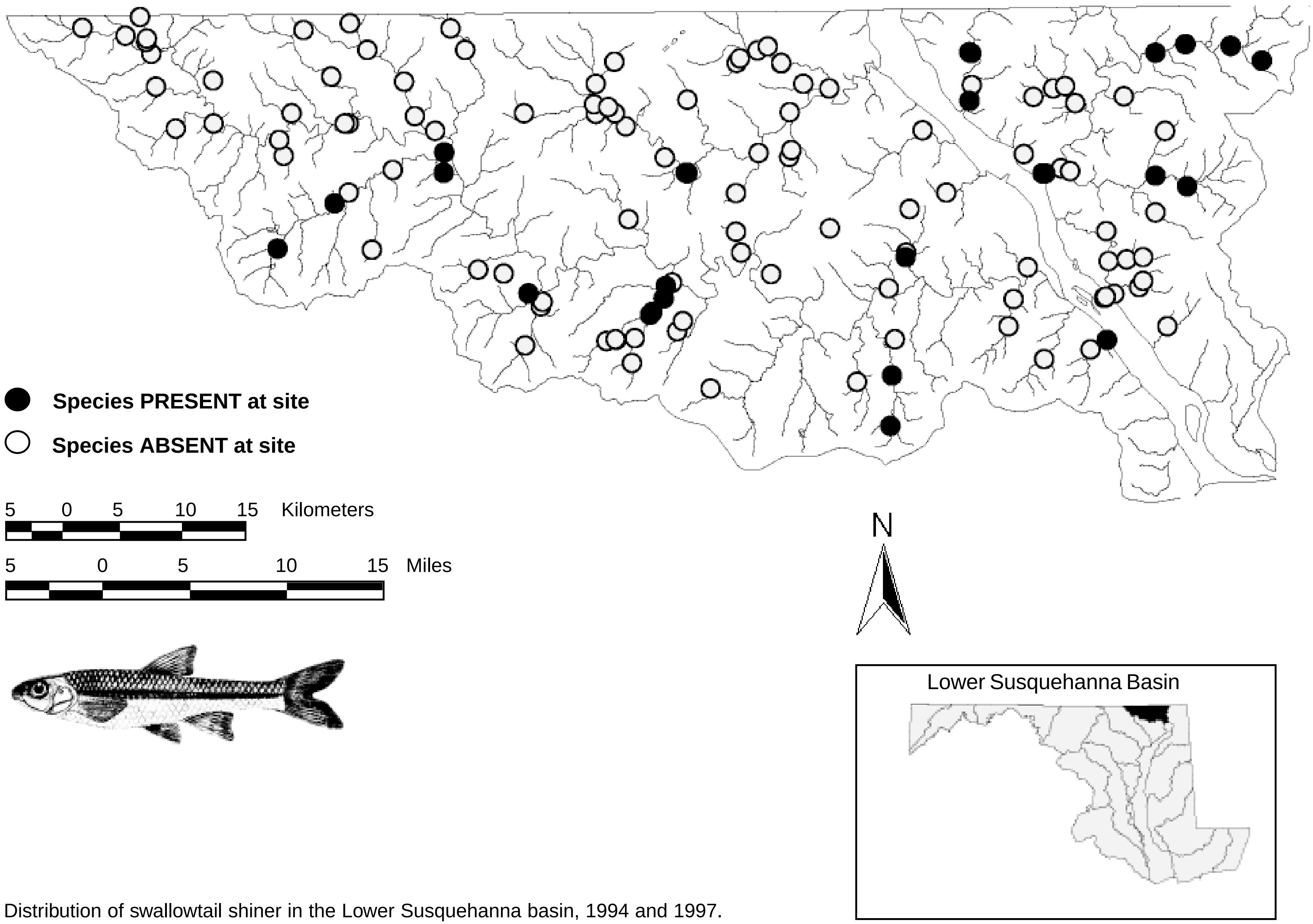
Distribution of spotfin shiner in the Lower Susquehanna basin, 1994 and 1997.



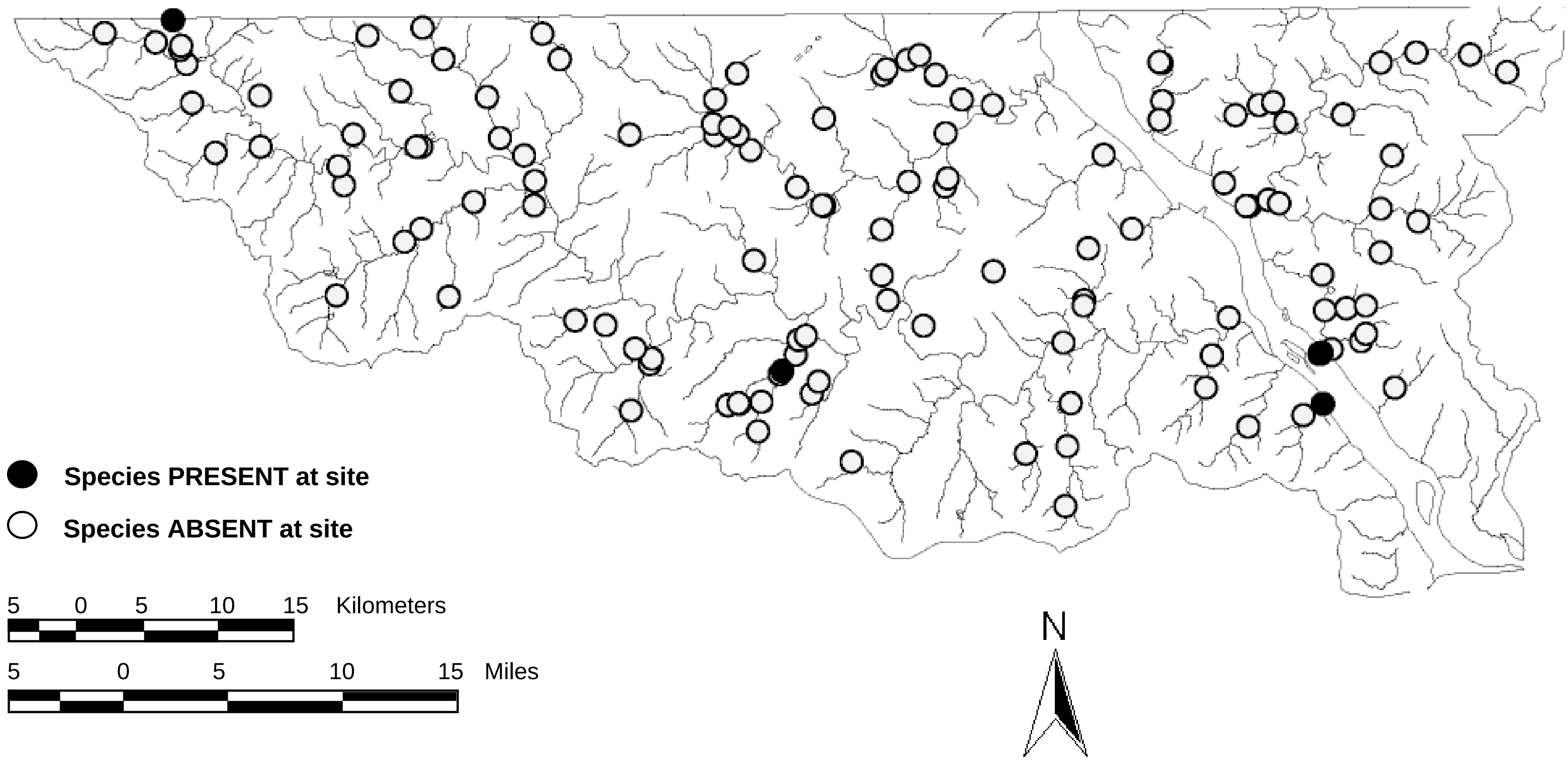


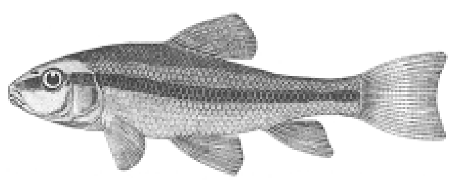


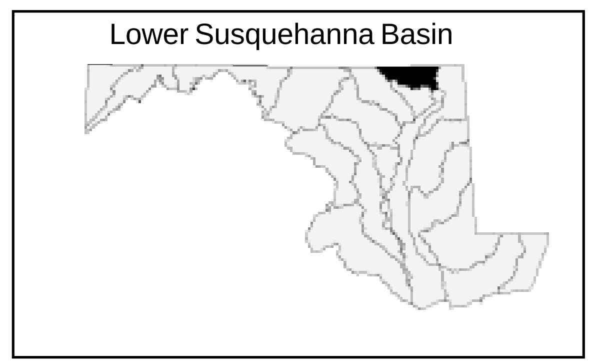
Distribution of spottail shiner in the Lower Susquehanna basin, 1994 and 1997.



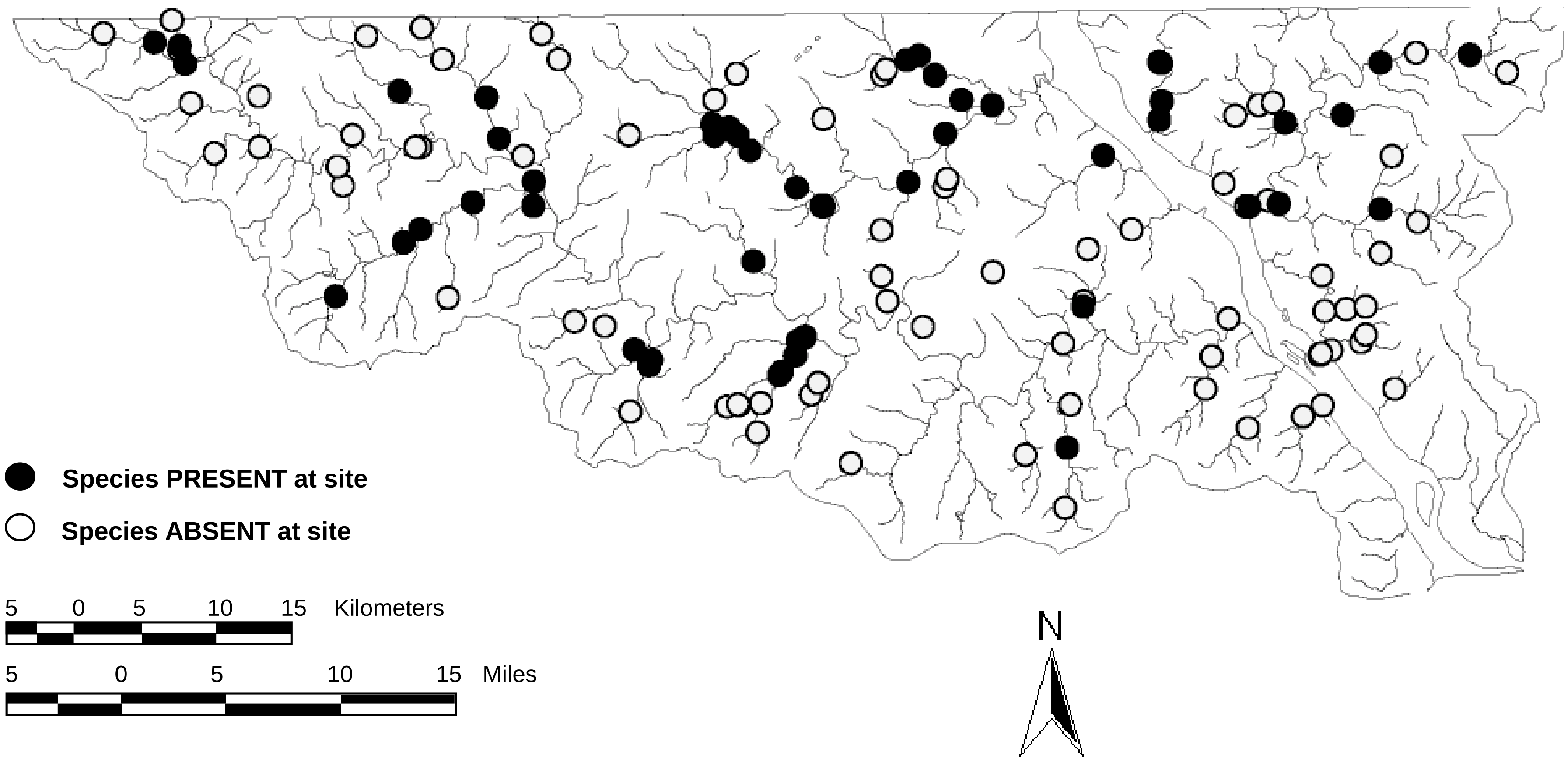
Distribution of swallowtail shiner in the Lower Susquehanna basin, 1994 and 1997.

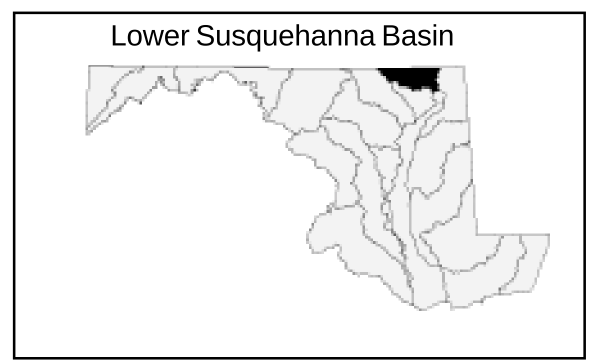




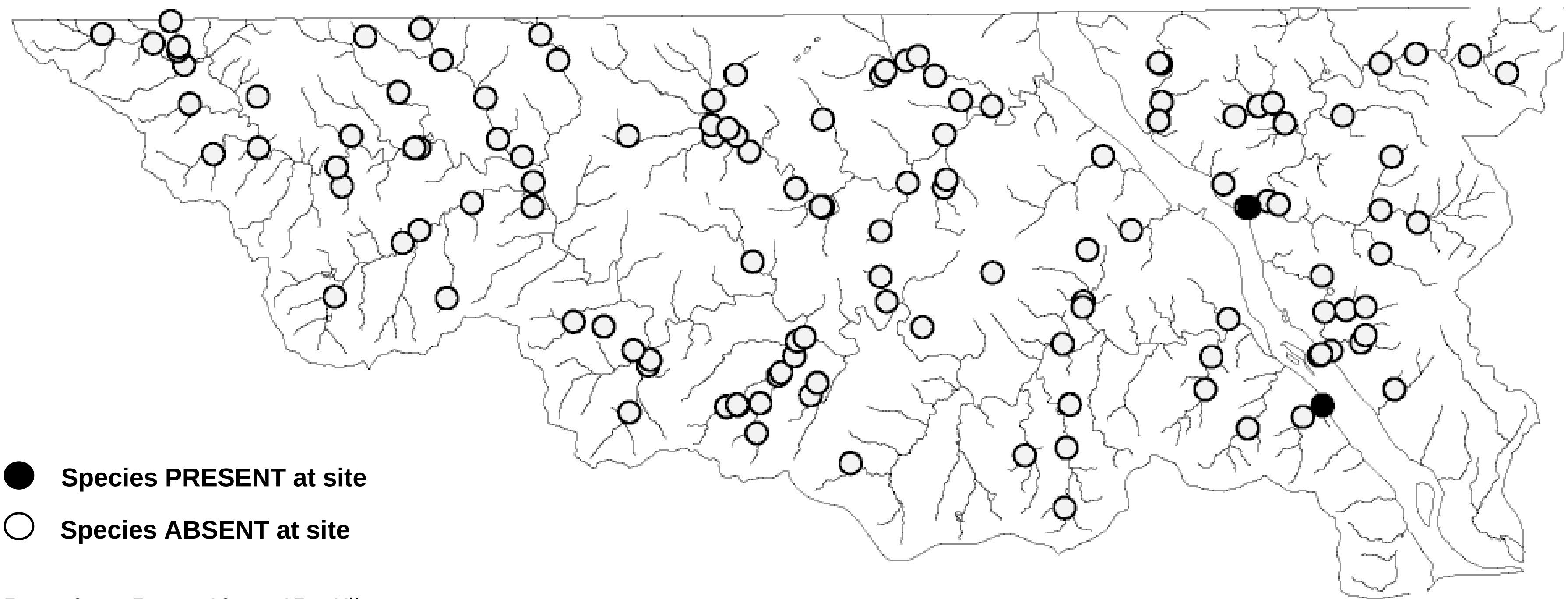


Distribution of creek chubsucker in the Lower Susquehanna basin, 1994 and 1997.



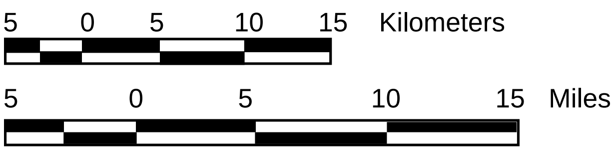


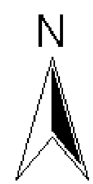
Distribution of northern hogsucker in the Lower Susquehanna basin, 1994 and 1997.

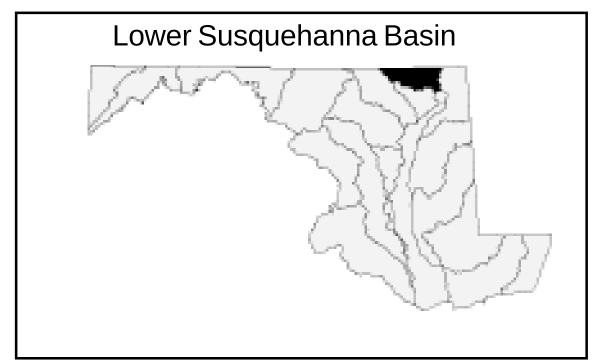


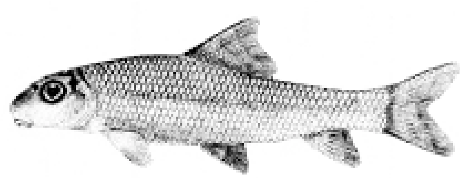
Species PRESENT at site

Species ABSENT at site

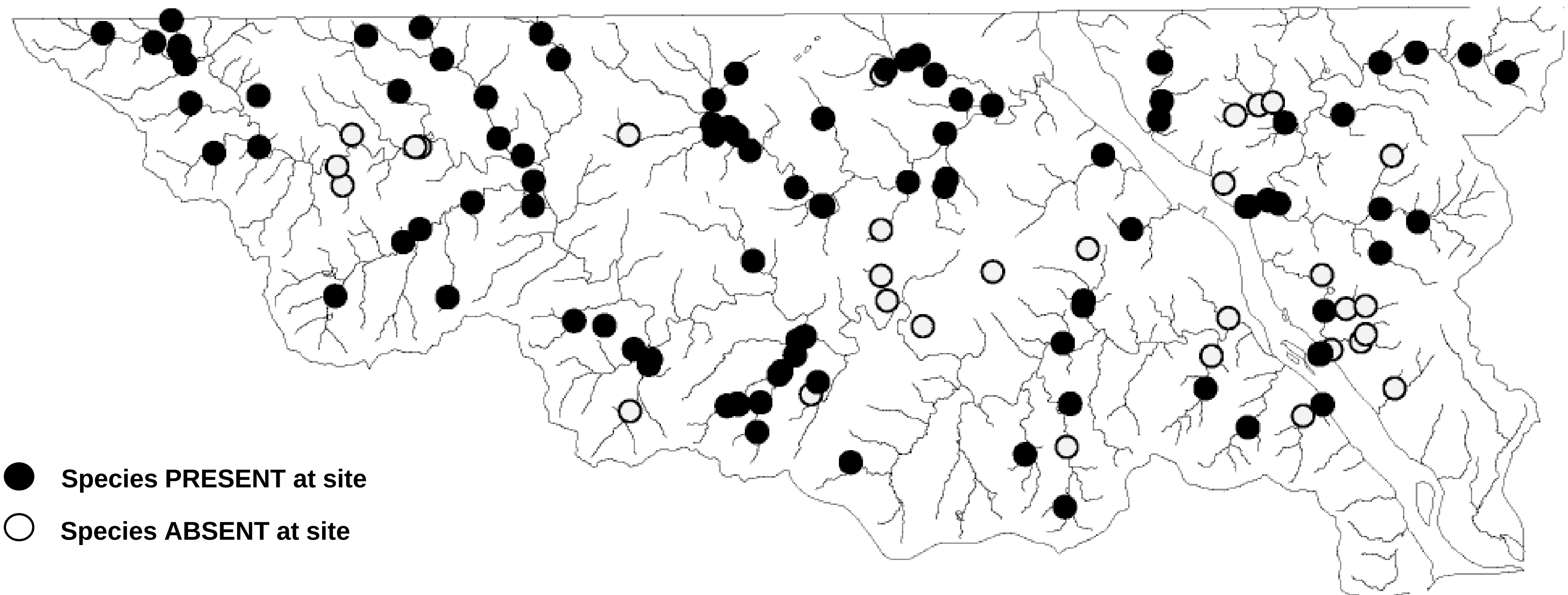








Distribution of shorthead redhorse in the Lower Susquehanna basin, 1994 and 1997.

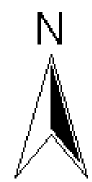


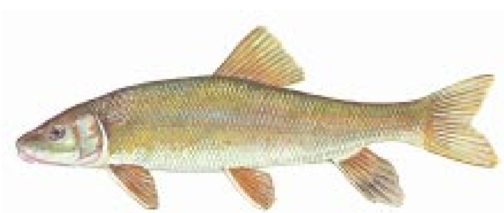
Species PRESENT at site

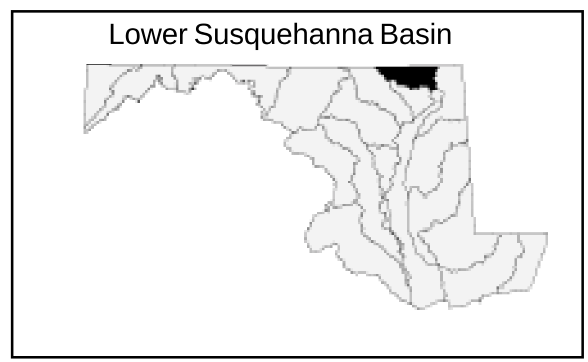
Species ABSENT at site

5 0 5 10 15 Kilometers

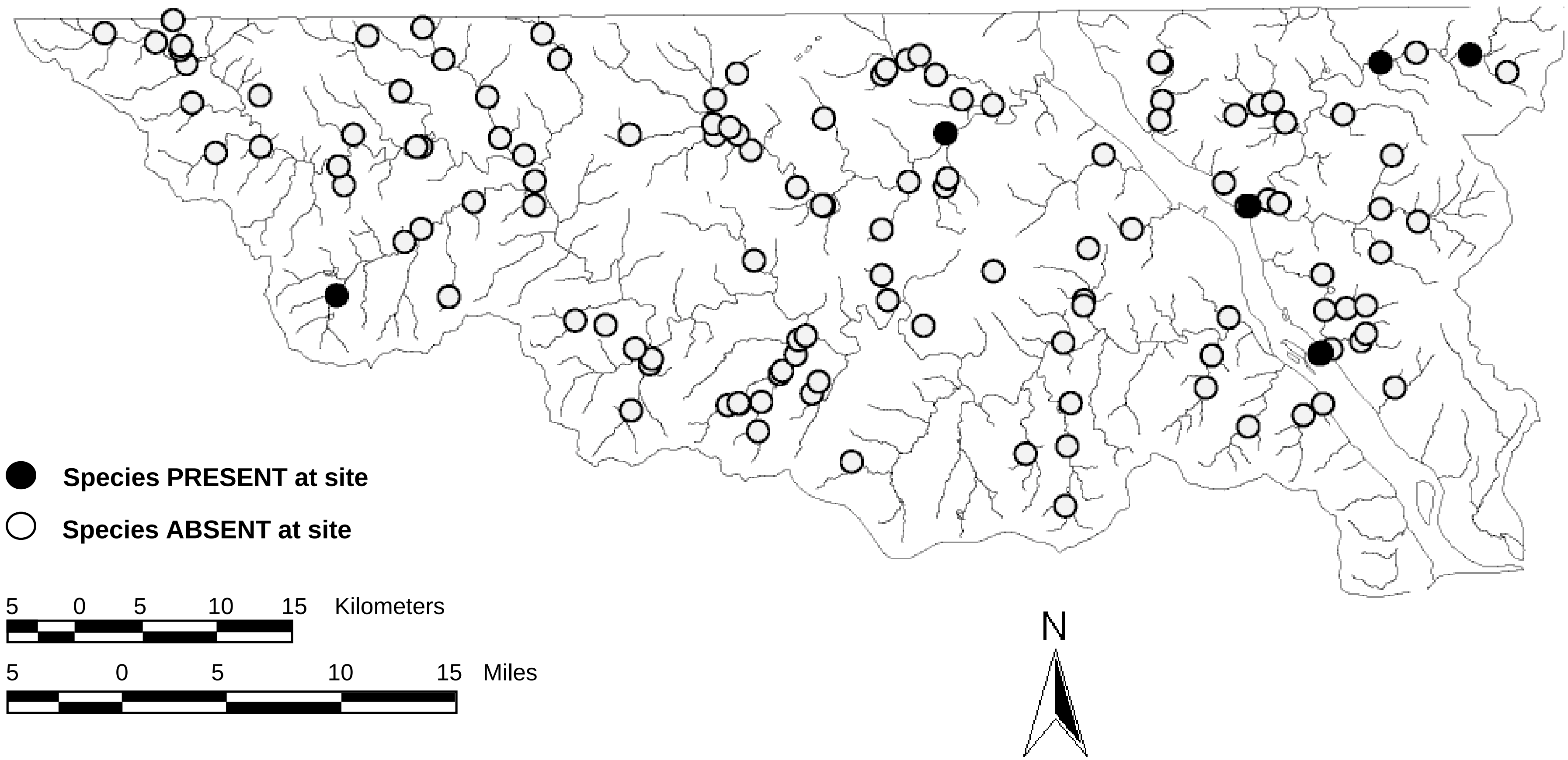
5 0 5 10 15 Miles

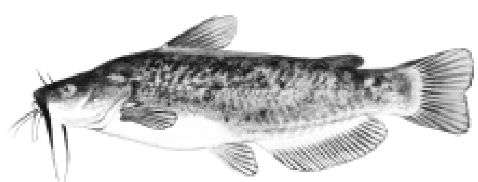


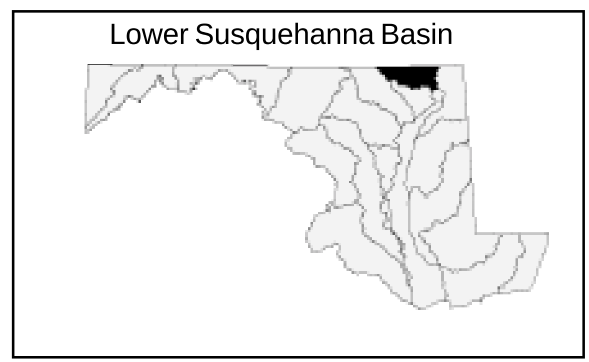




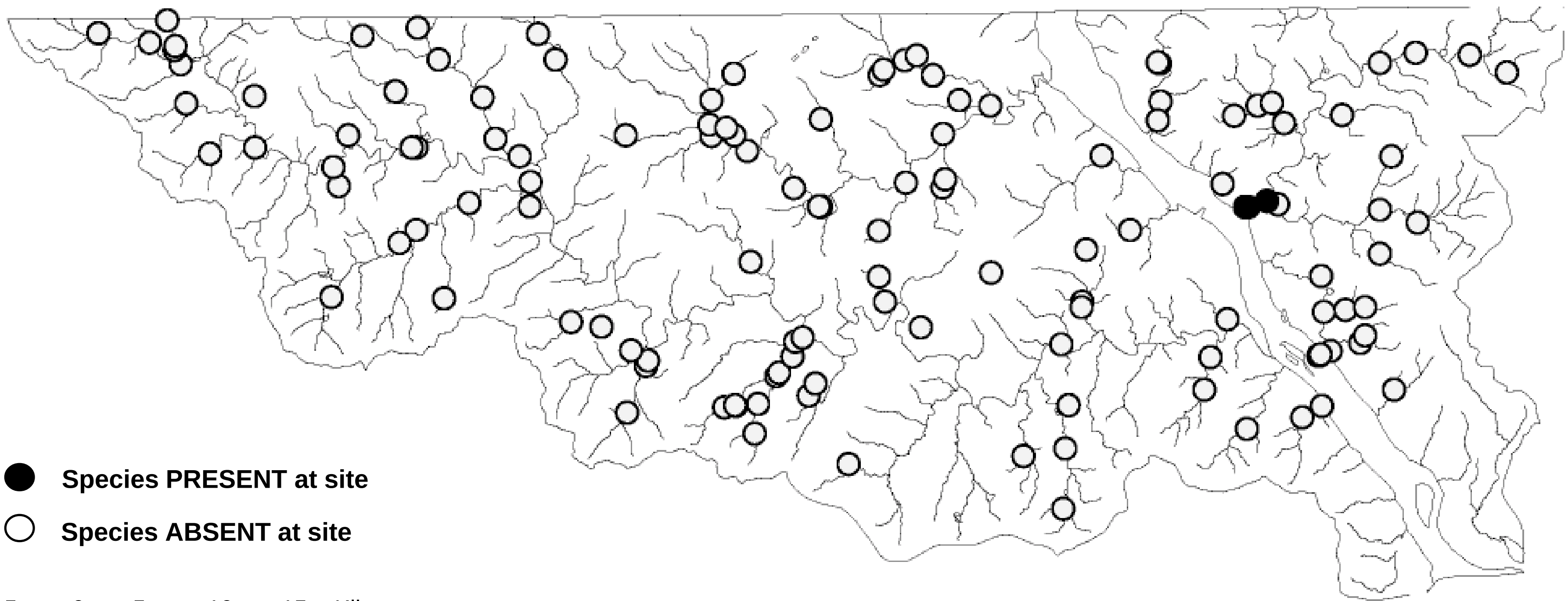
Distribution of white sucker in the Lower Susquehanna basin, 1994 and 1997.





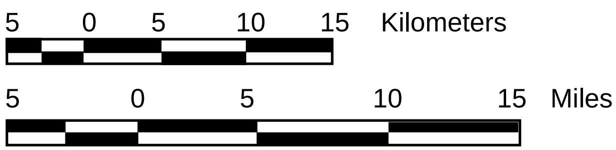


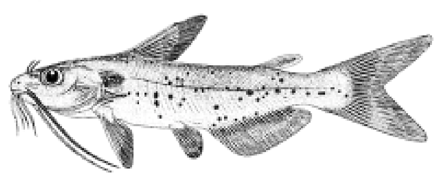
Distribution of brown bullhead in the Lower Susquehanna basin, 1994 and 1997.

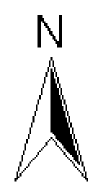


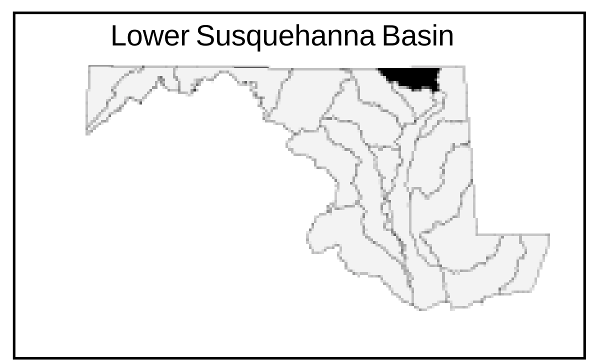
Species PRESENT at site

Species ABSENT at site

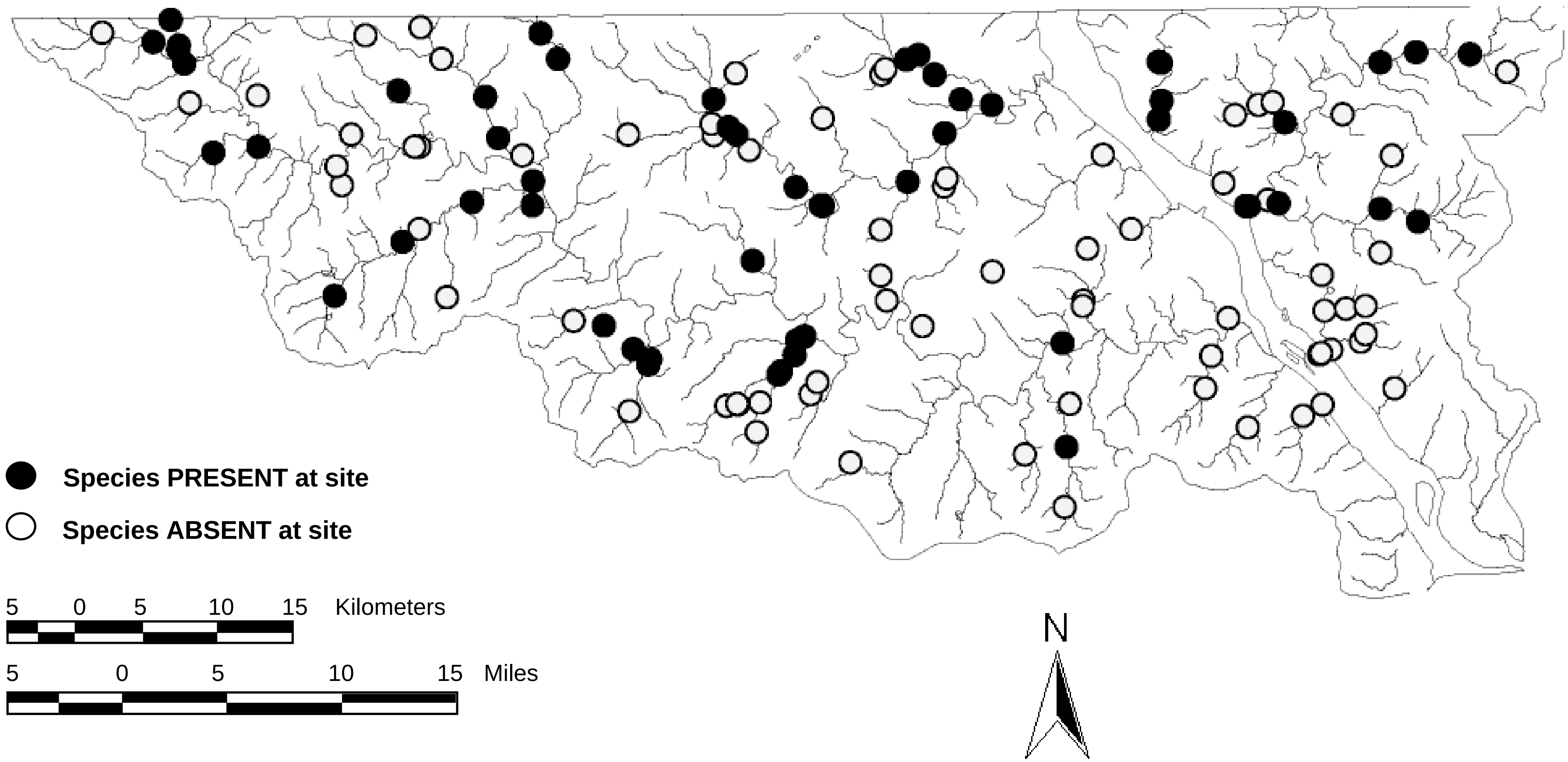


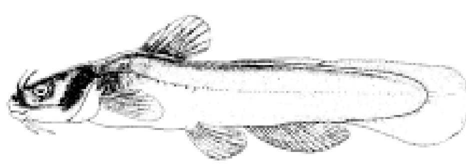


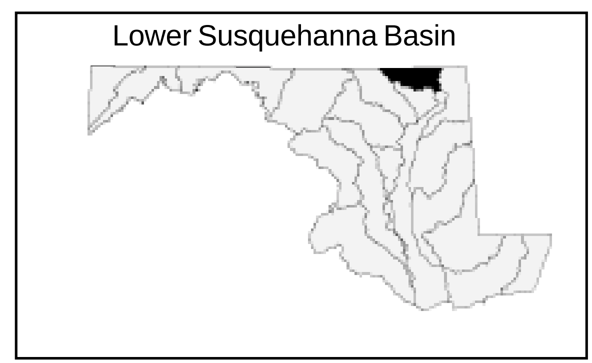




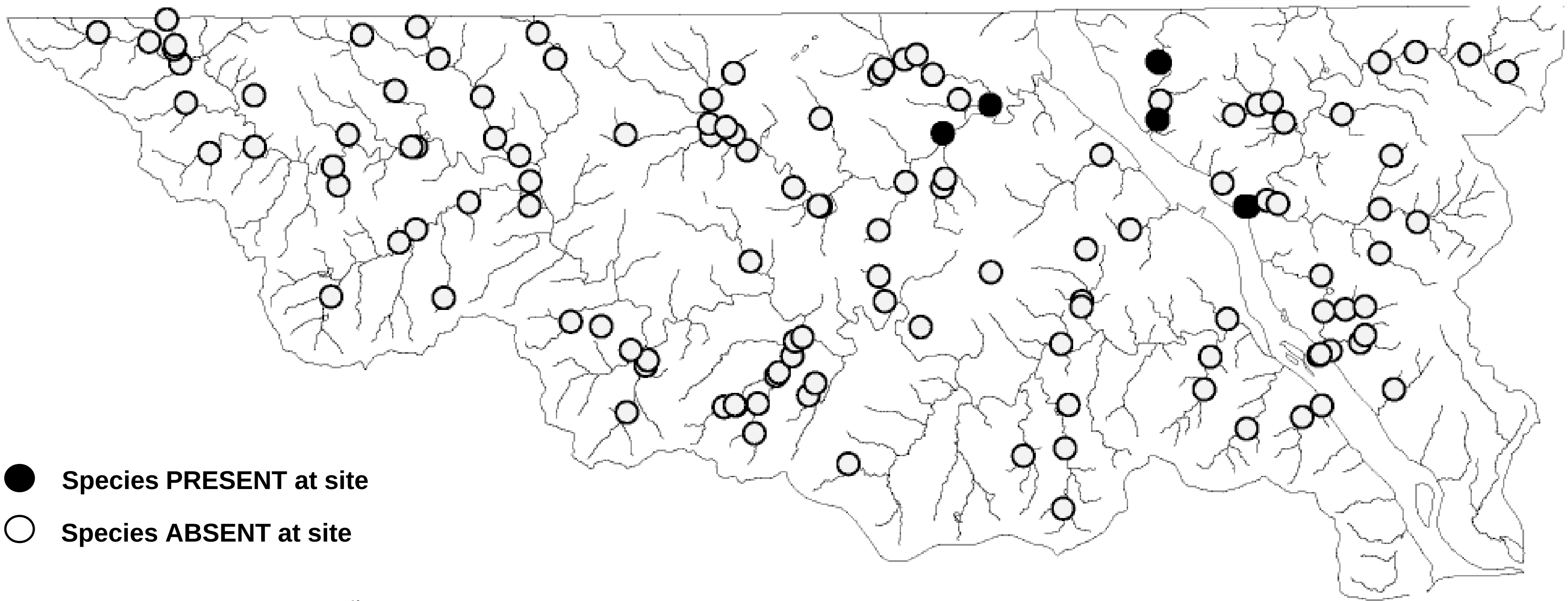
Distribution of channel catfish in the Lower Susquehanna basin, 1994 and 1997.







Distribution of margined madtom in the Lower Susquehanna basin, 1994 and 1997.



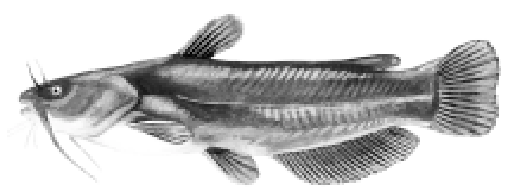
Species PRESENT at site

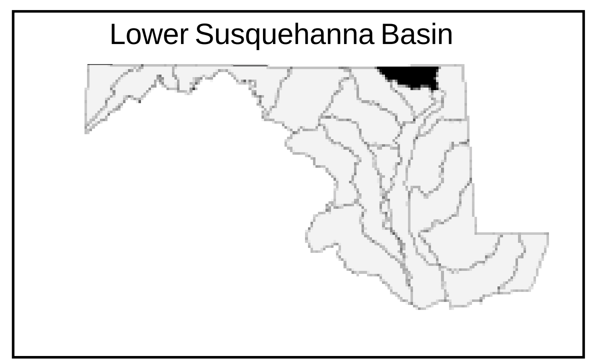
Species ABSENT at site

5 0 5 10 15 Kilometers

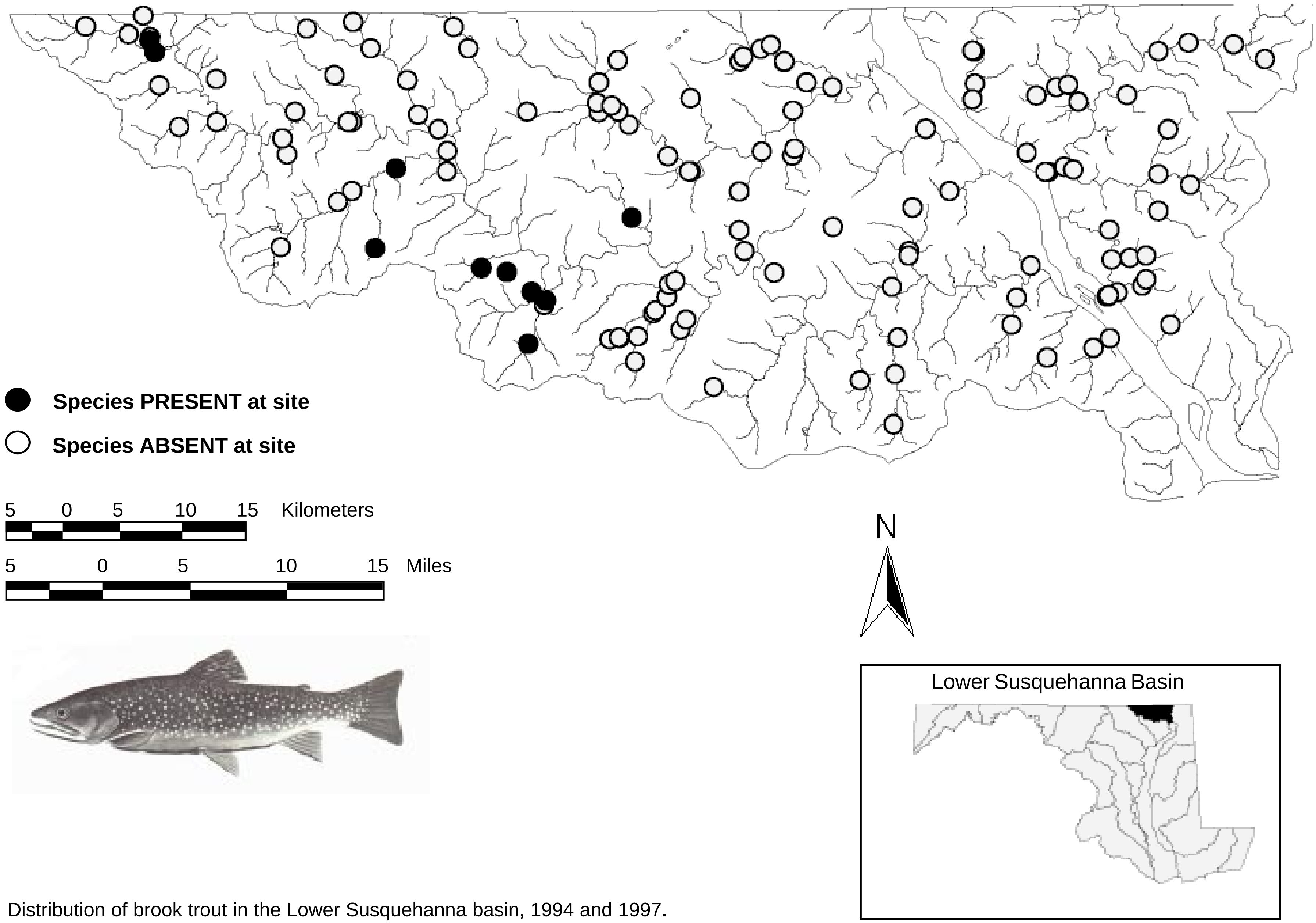
5 0 5 10 15 Miles

N

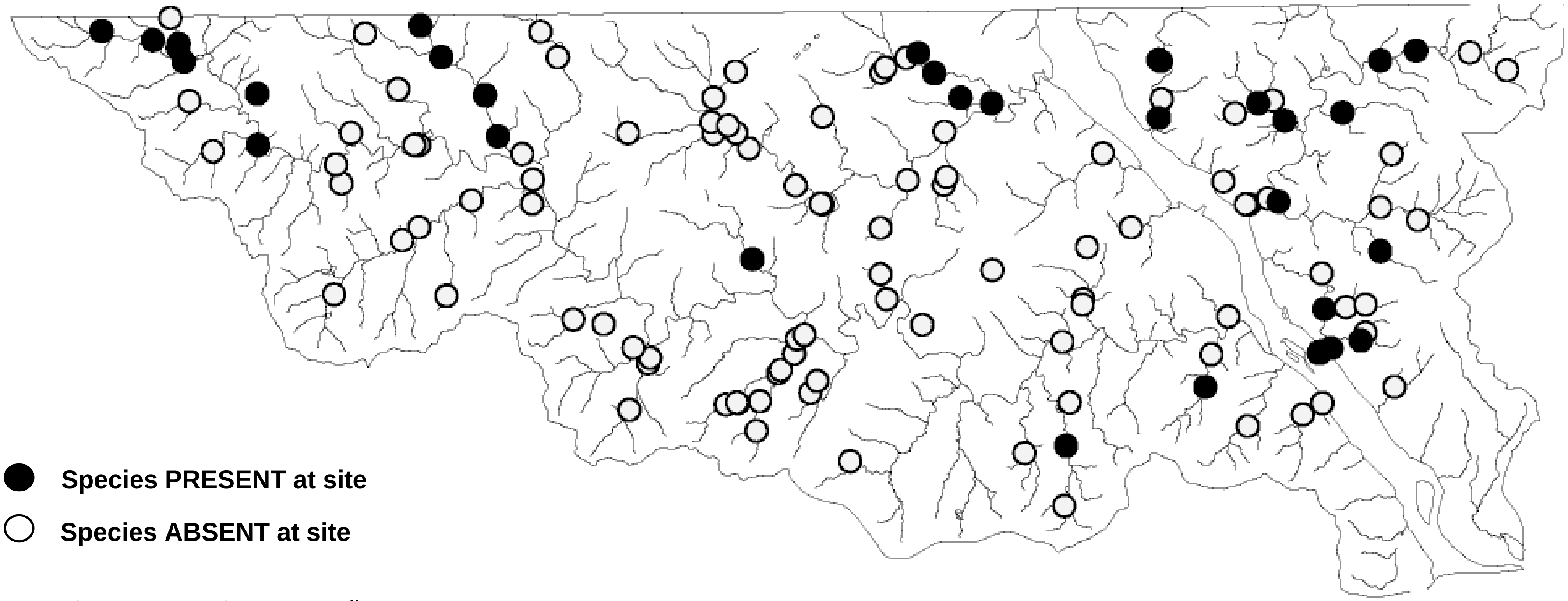




Distribution of yellow bullhead in the Lower Susquehanna basin, 1994 and 1997.



Distribution of brook trout in the Lower Susquehanna basin, 1994 and 1997.

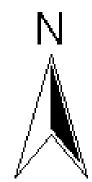


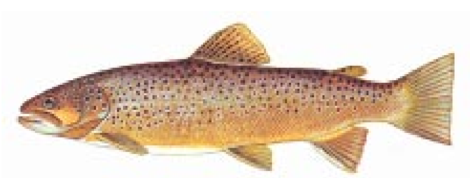
● **Species PRESENT at site**

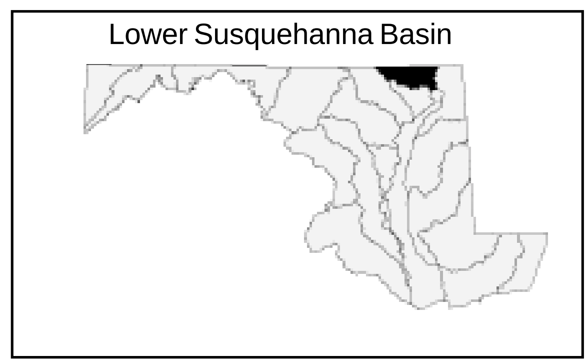
○ **Species ABSENT at site**

5 0 5 10 15 Kilometers

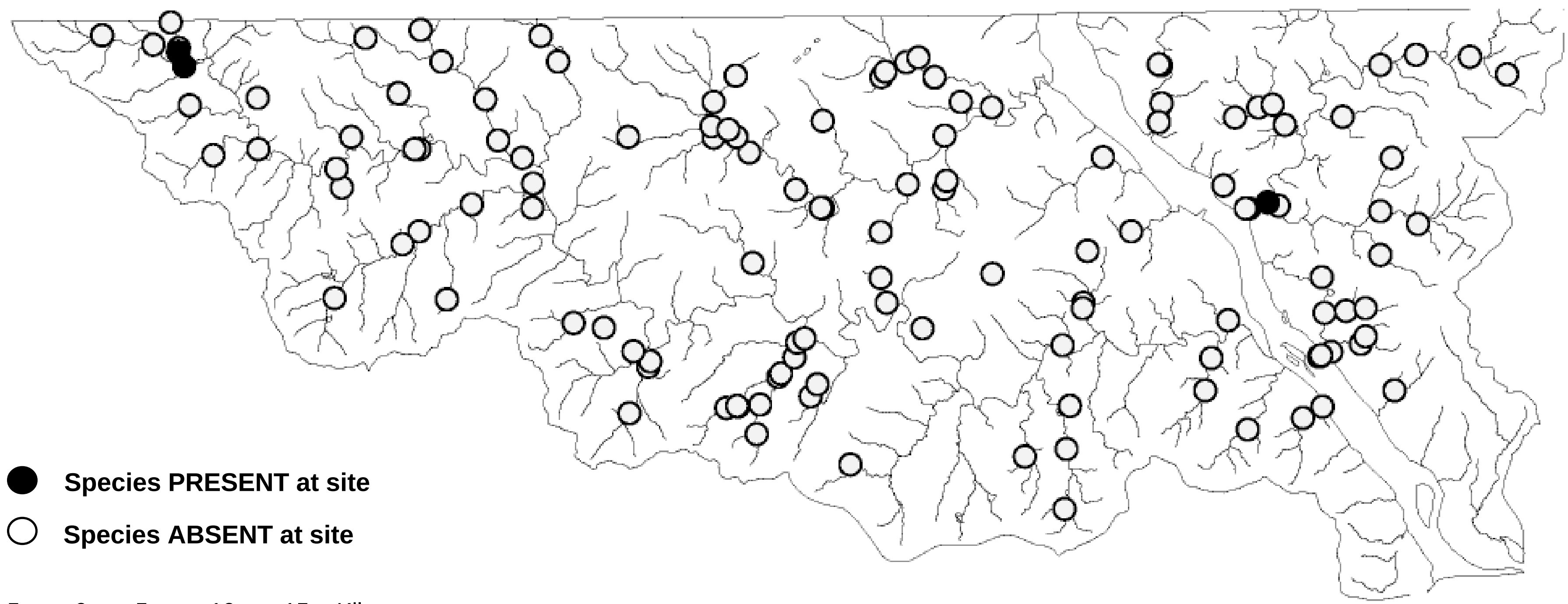
5 0 5 10 15 Miles

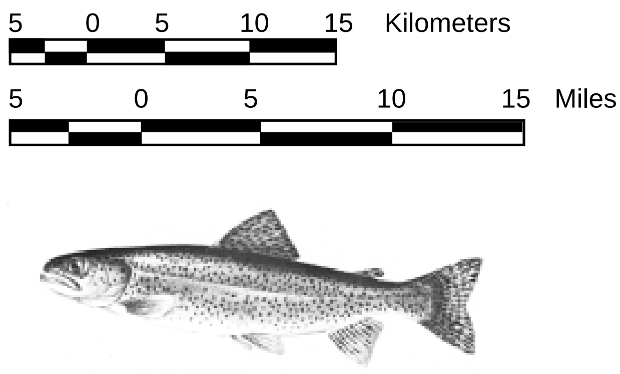


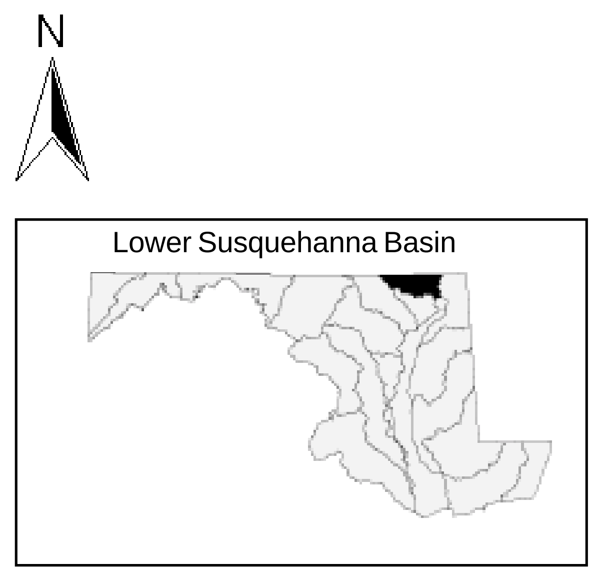




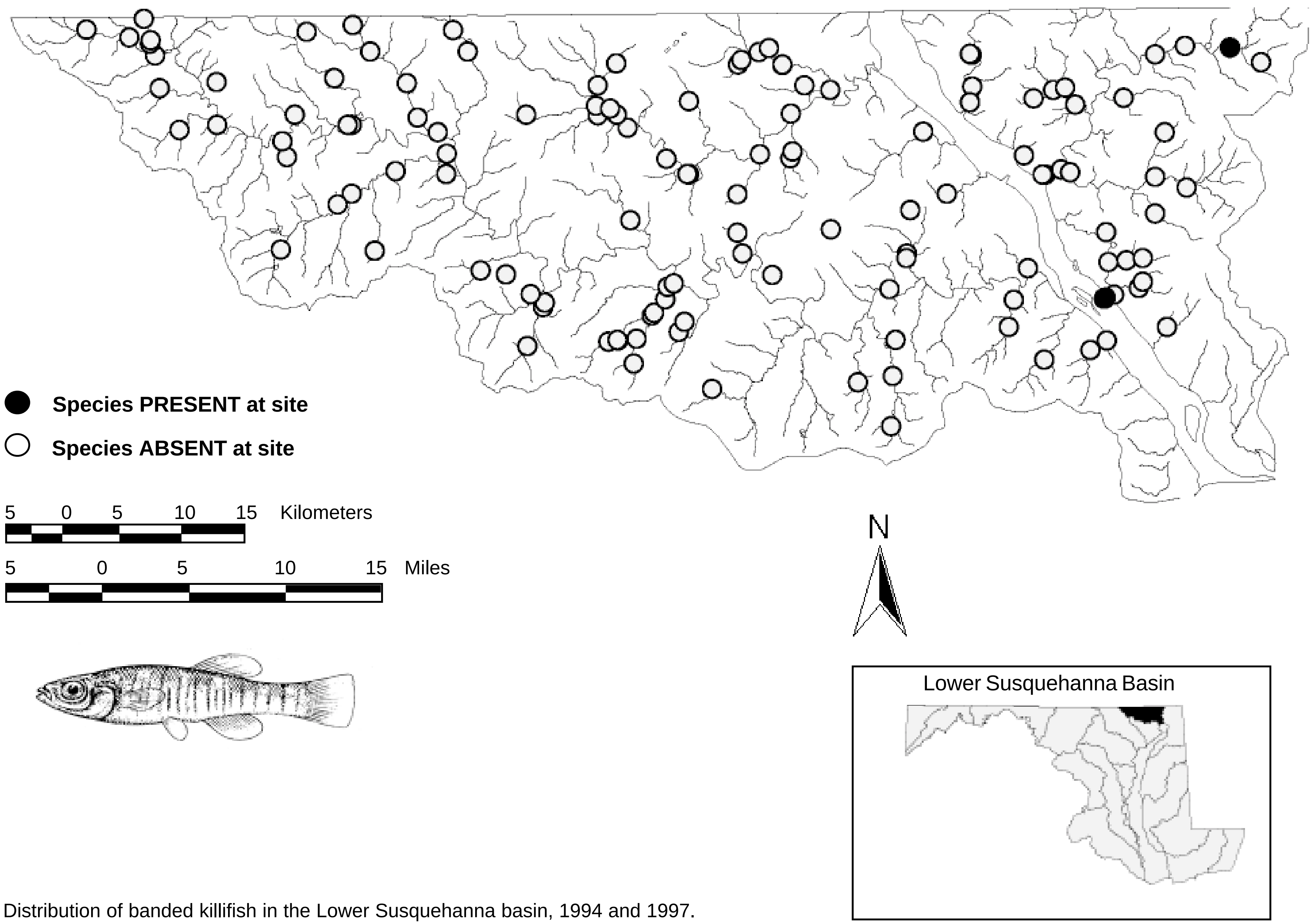
Distribution of brown trout in the Lower Susquehanna basin, 1994 and 1997.



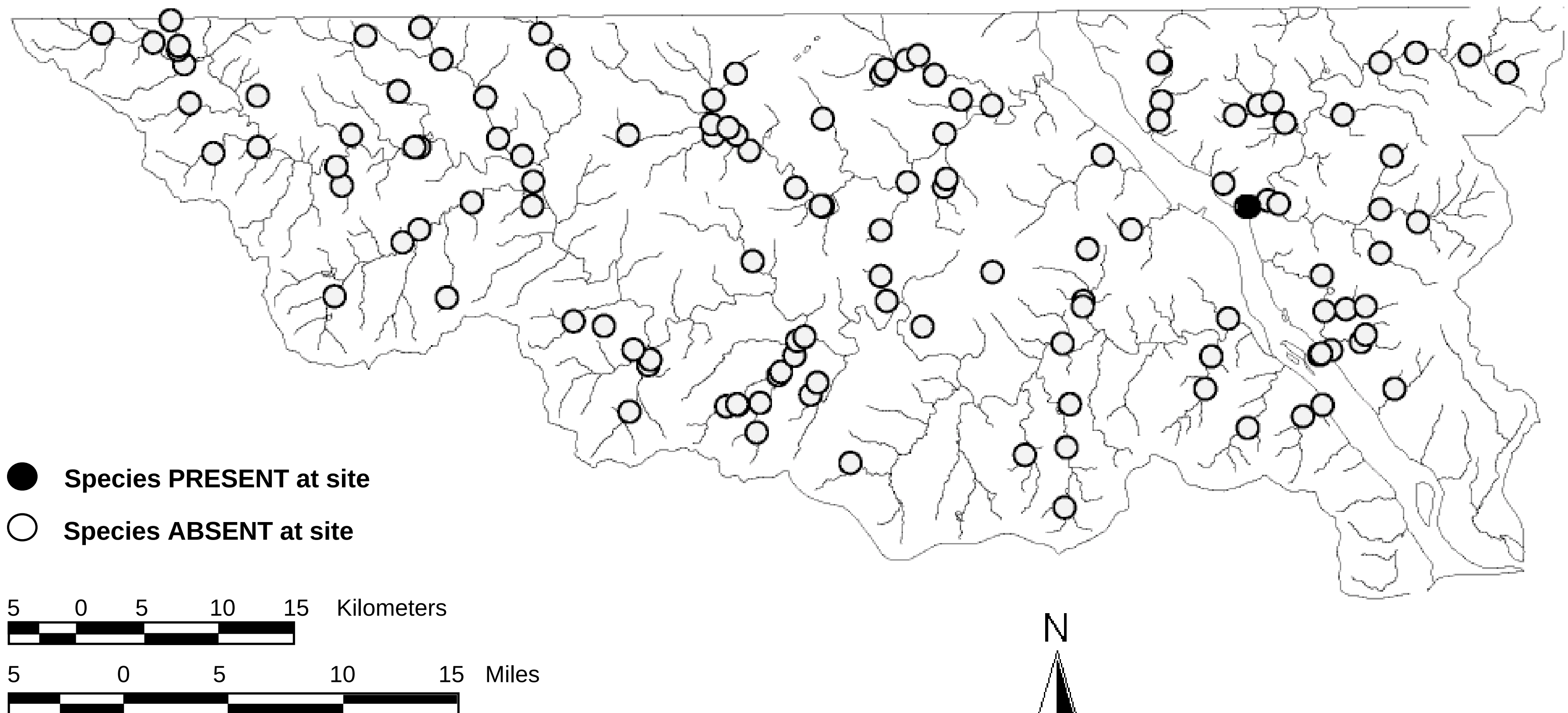


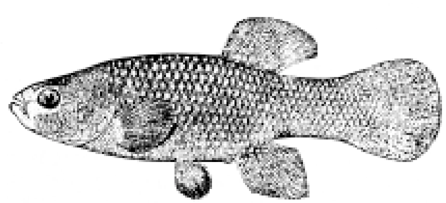


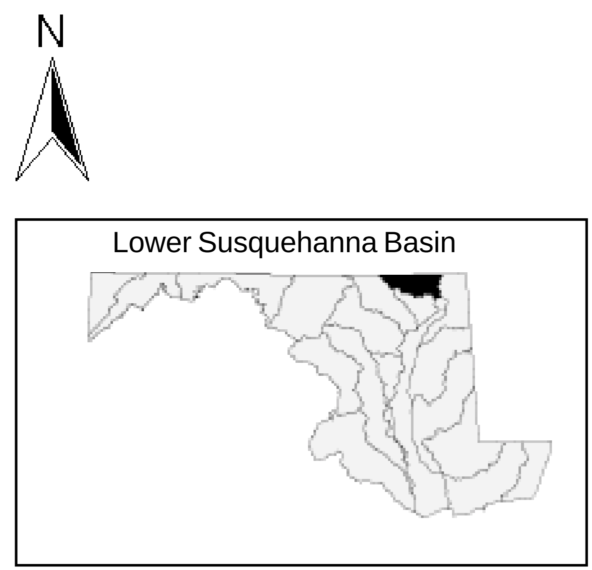
Distribution of rainbow trout in the Lower Susquehanna basin, 1994 and 1997.



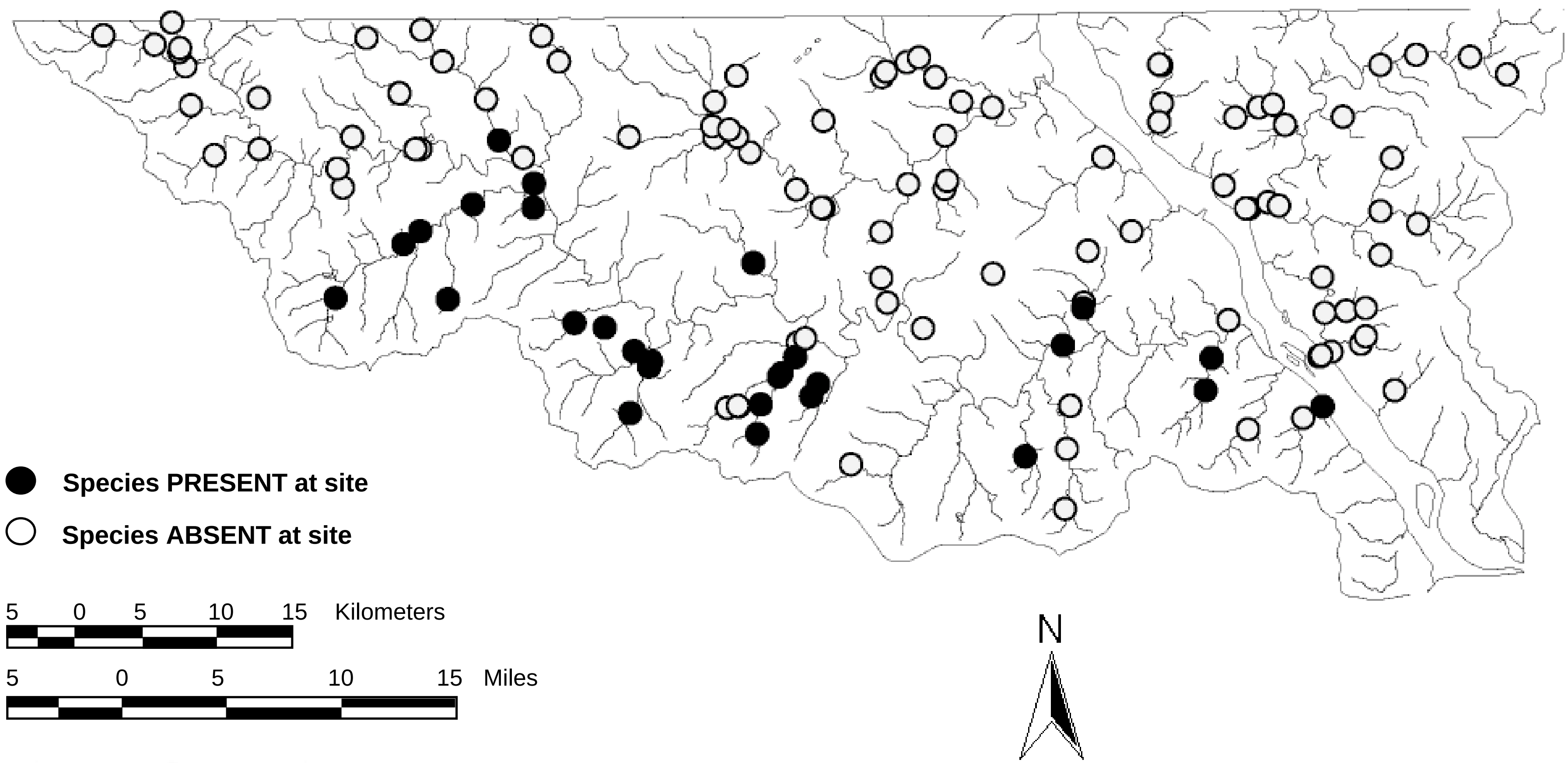
Distribution of banded killifish in the Lower Susquehanna basin, 1994 and 1997.

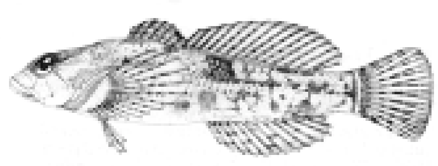


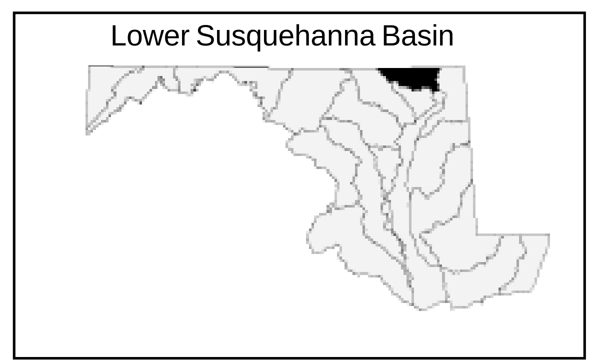




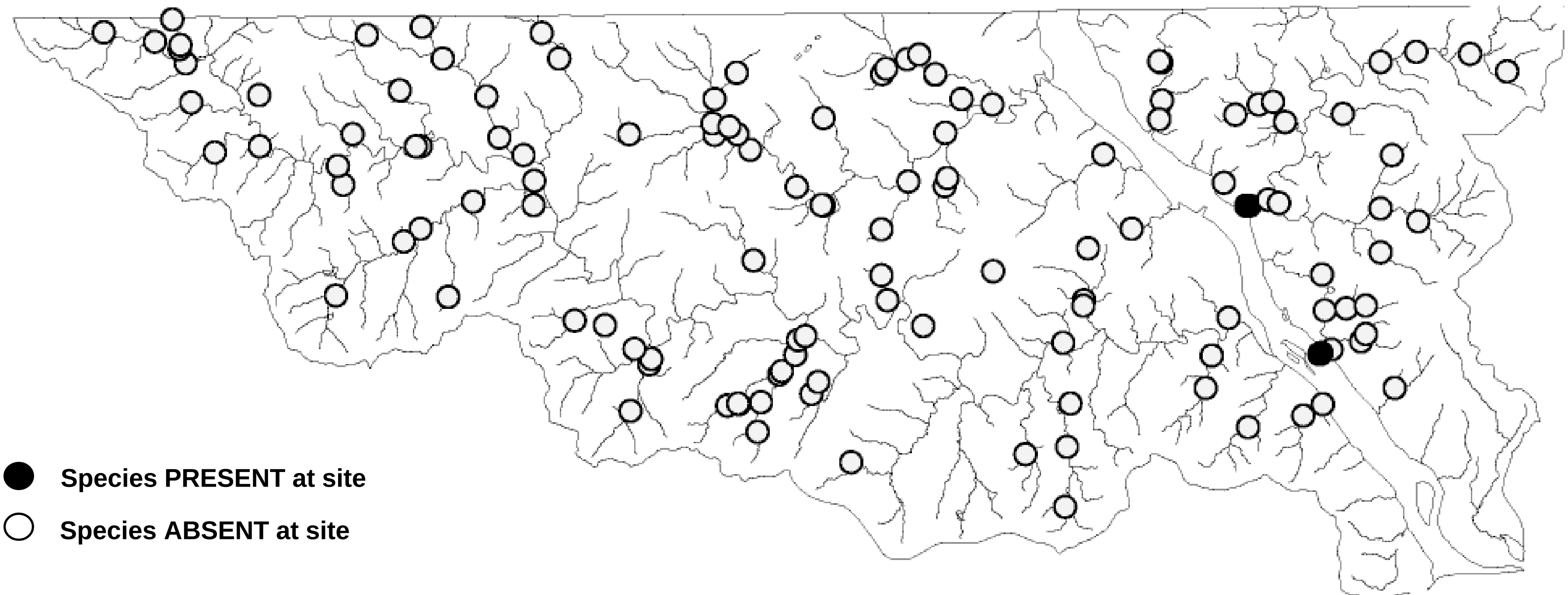
Distribution of mummichog in the Lower Susquehanna basin, 1994 and 1997.







Distribution of mottled sculpin in the Lower Susquehanna basin, 1994 and 1997.

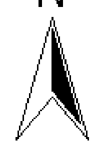


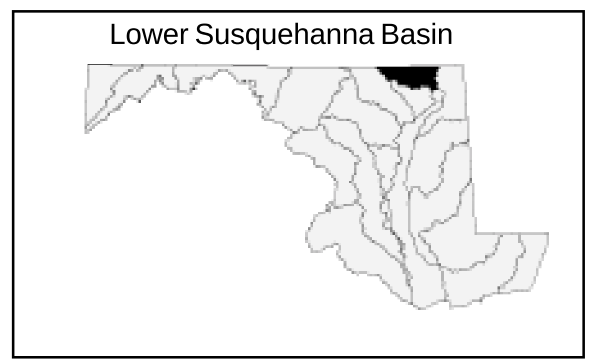
● **Species PRESENT at site**

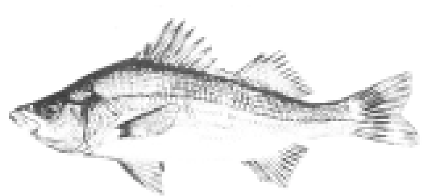
○ **Species ABSENT at site**

5 0 5 10 15 Kilometers

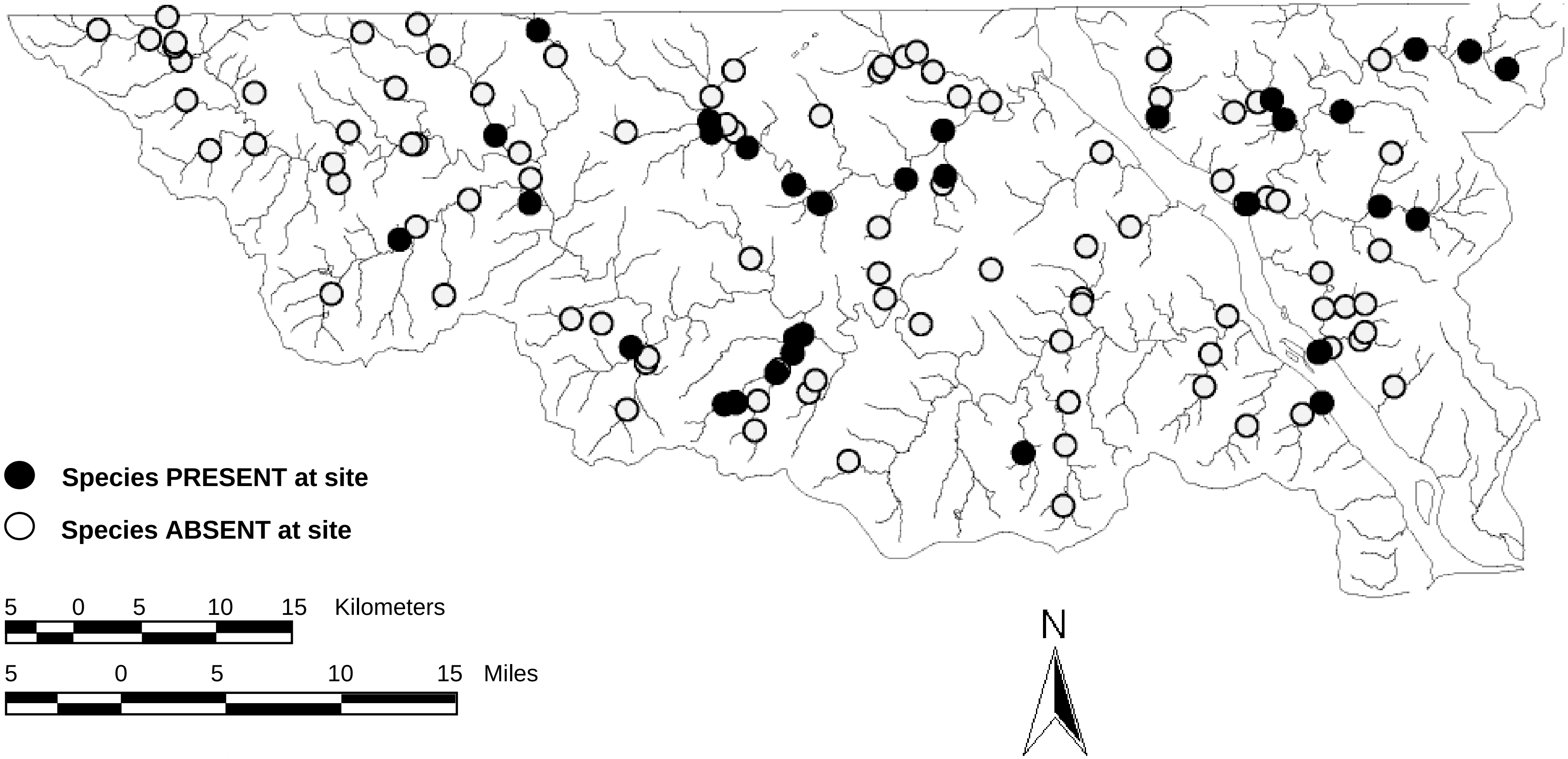
5 0 5 10 15 Miles

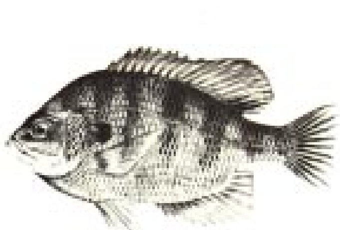


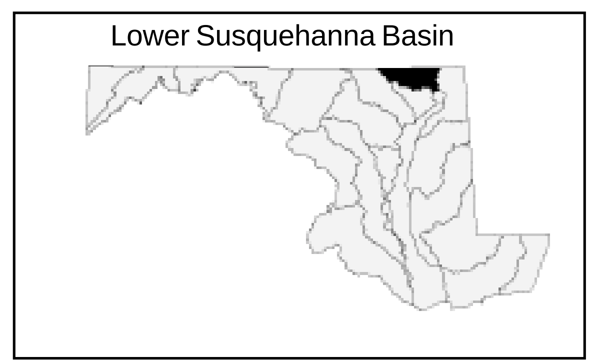




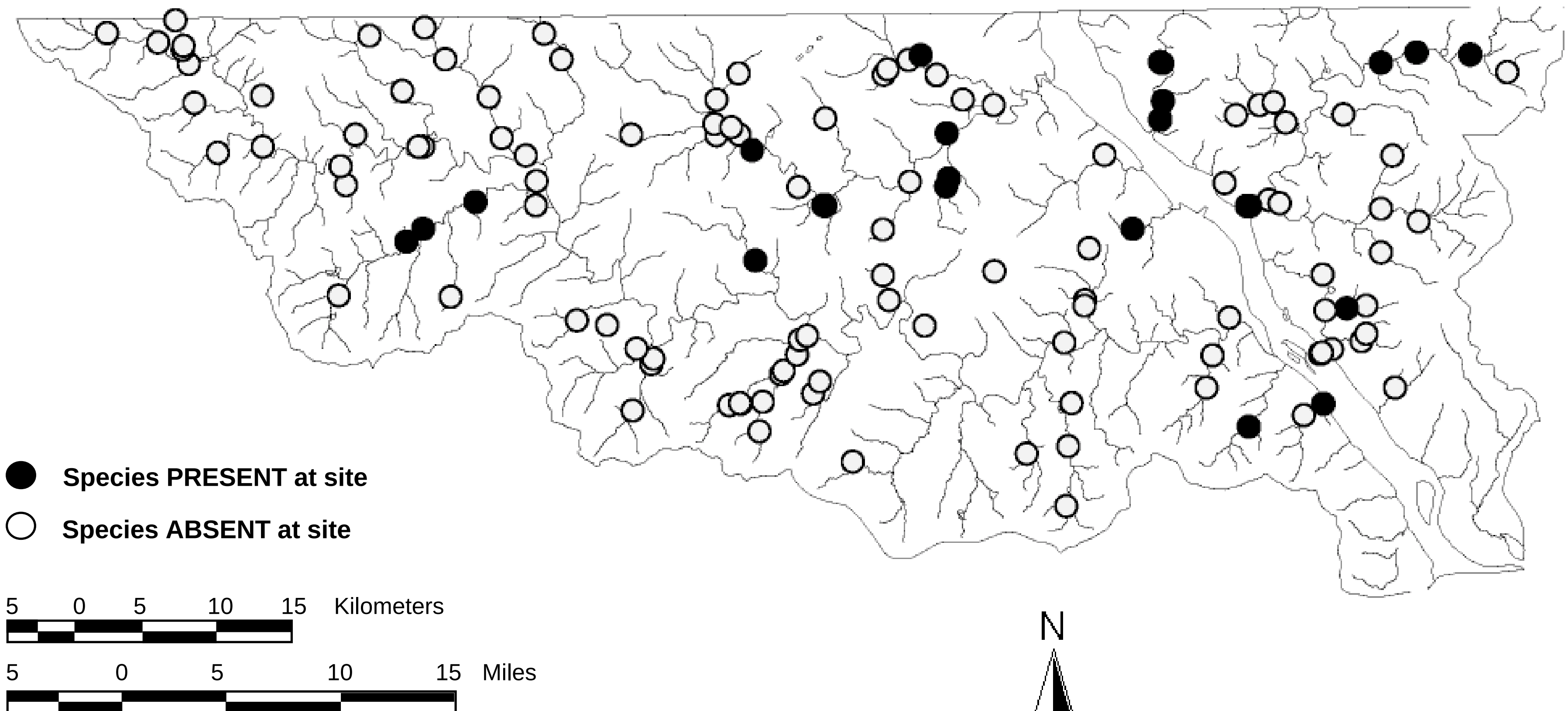
Distribution of white perch in the Lower Susquehanna basin, 1994 and 1997.

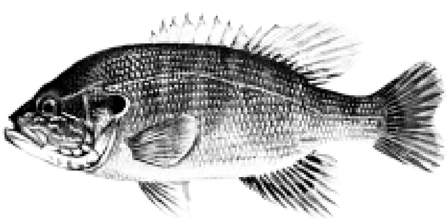


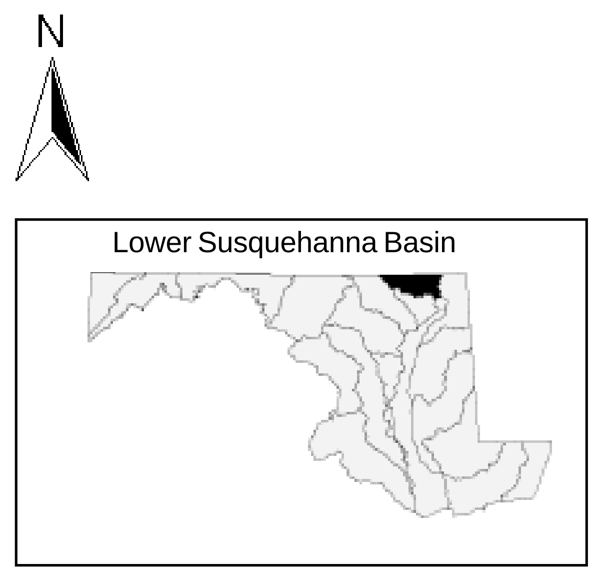




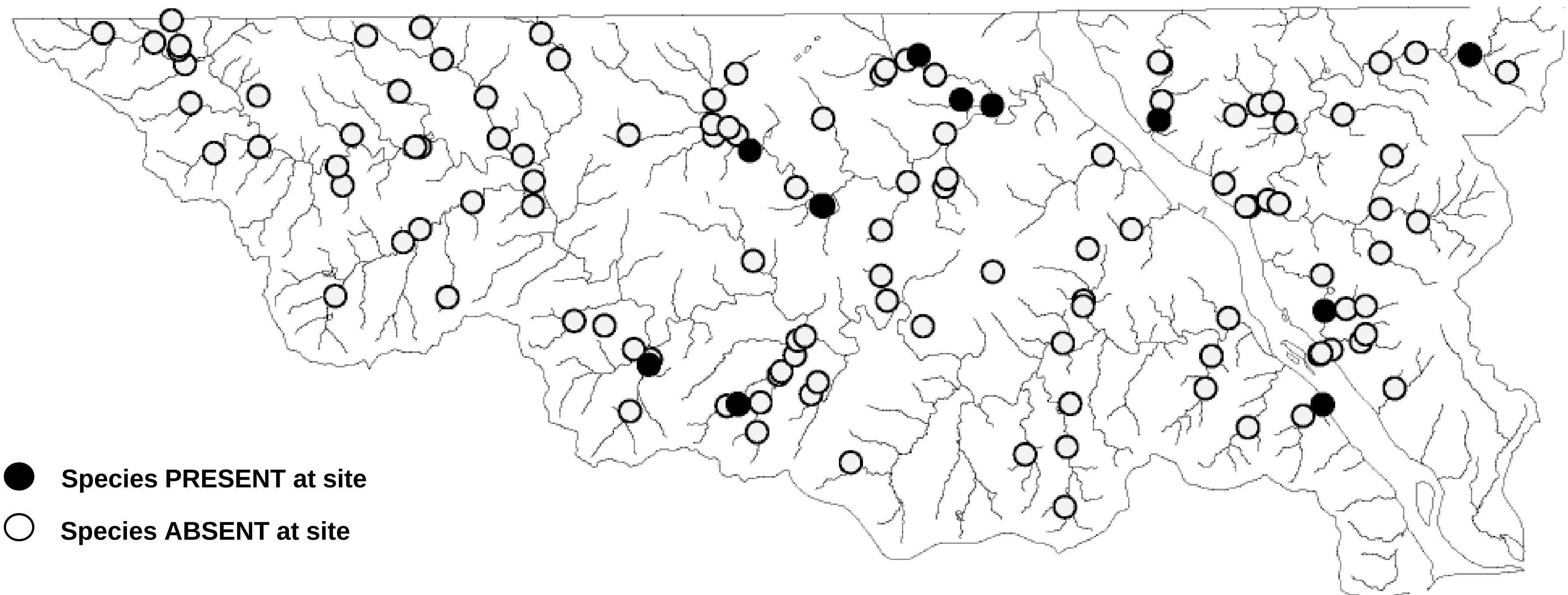
Distribution of bluegill in the Lower Susquehanna basin, 1994 and 1997.





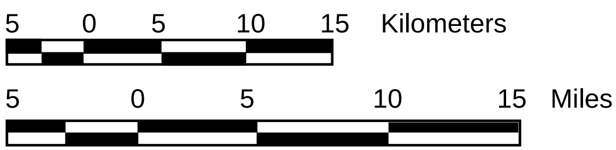


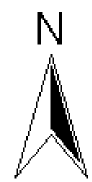
Distribution of green sunfish in the Lower Susquehanna basin, 1994 and 1997.

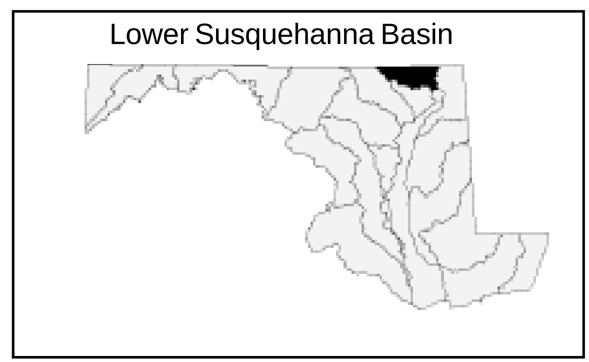


● **Species PRESENT at site**

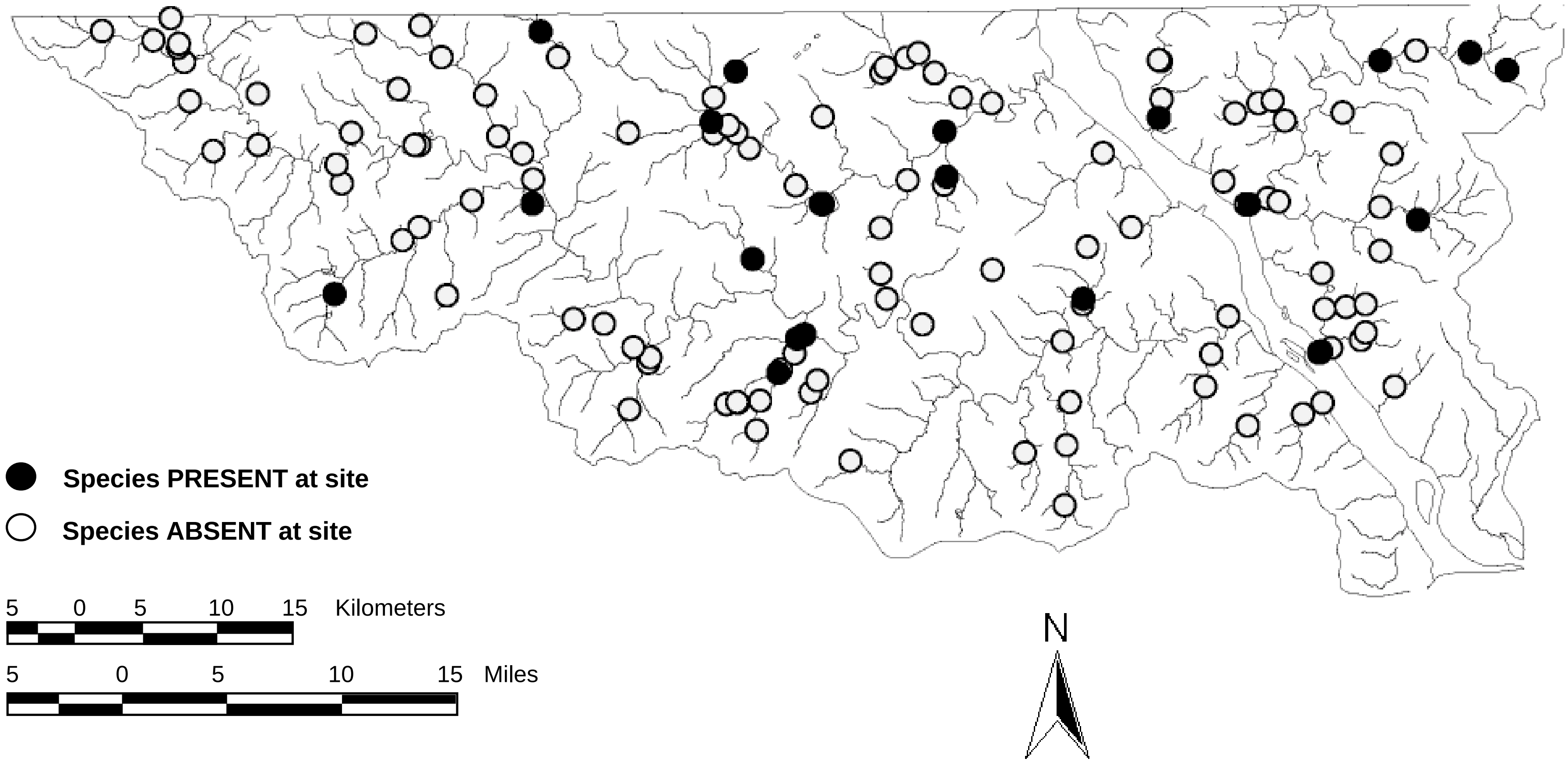
○ **Species ABSENT at site**

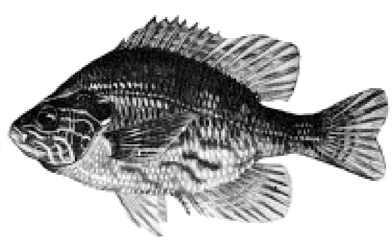


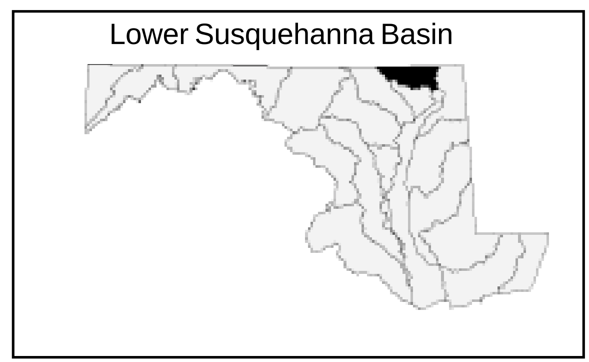




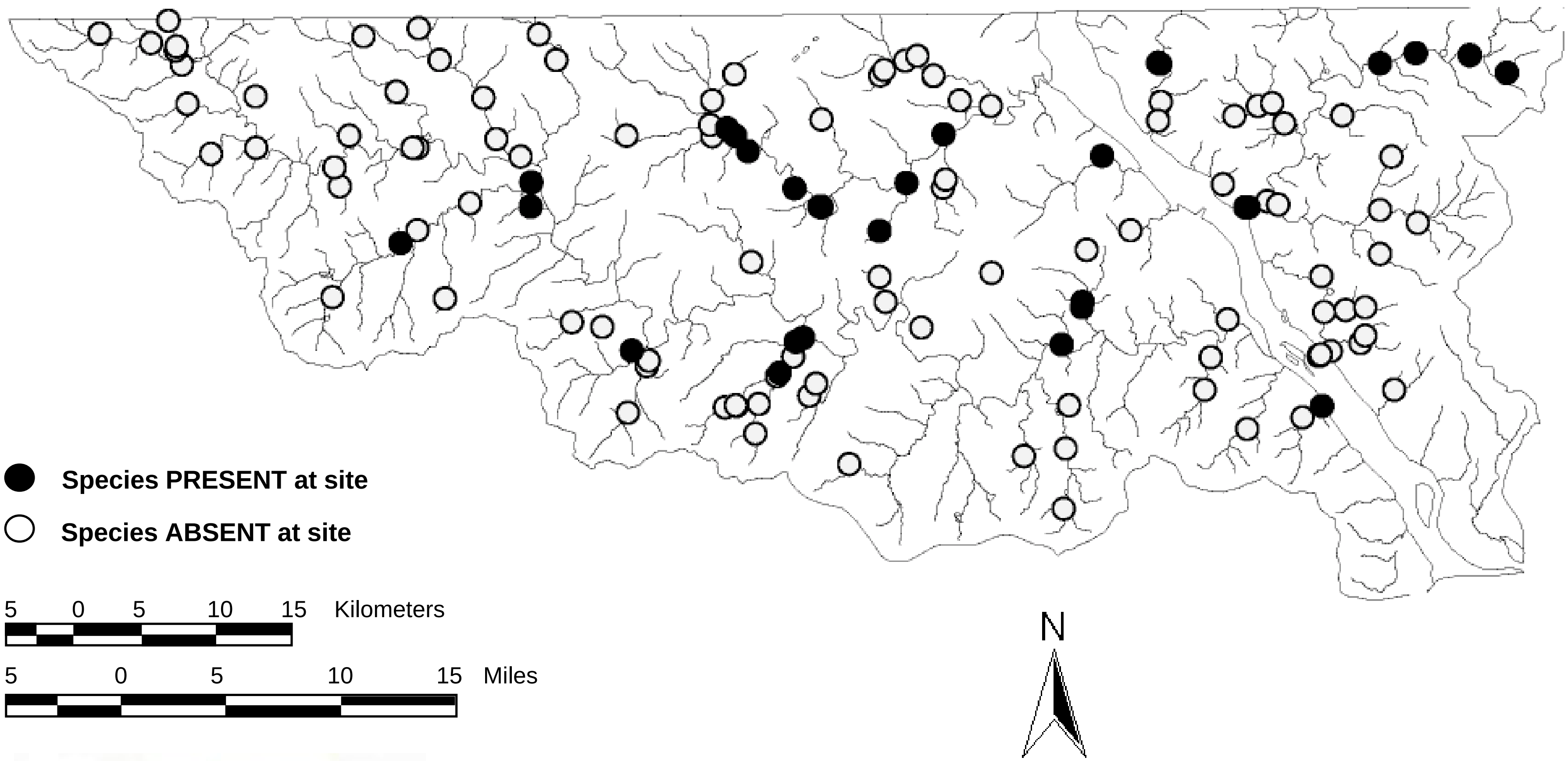
Distribution of largemouth bass in the Lower Susquehanna basin, 1994 and 1997.

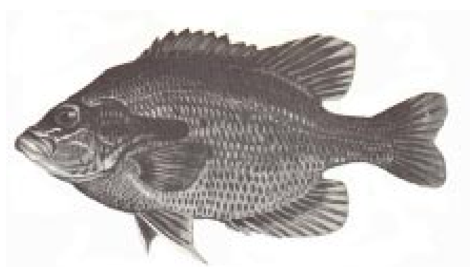


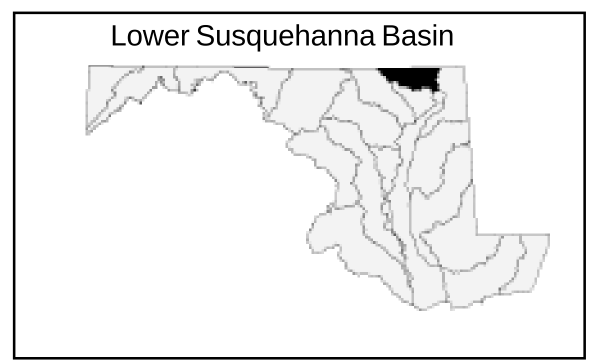




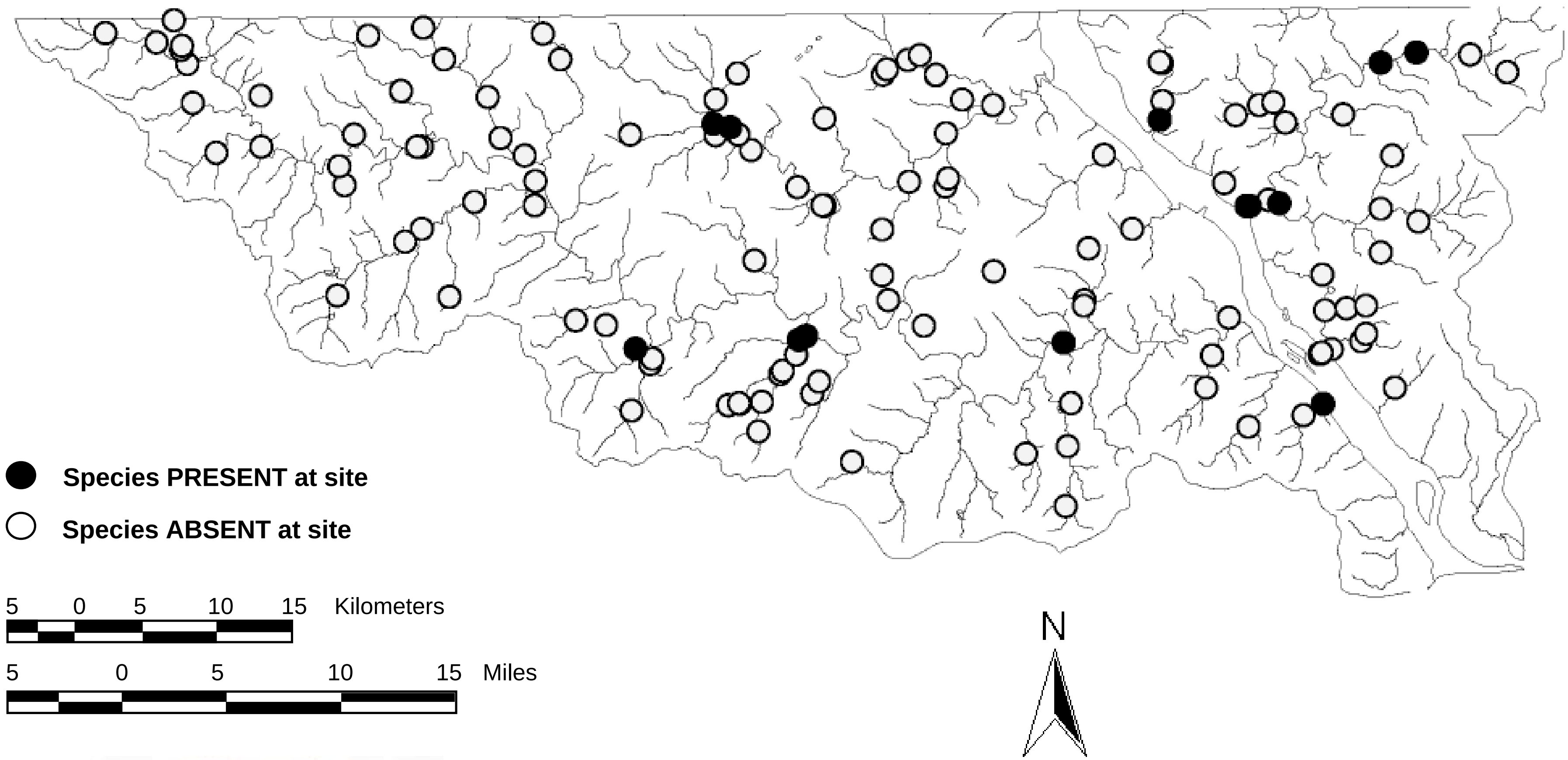
Distribution of pumpkinseed in the Lower Susquehanna basin, 1994 and 1997.

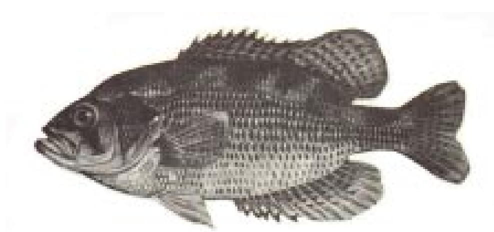


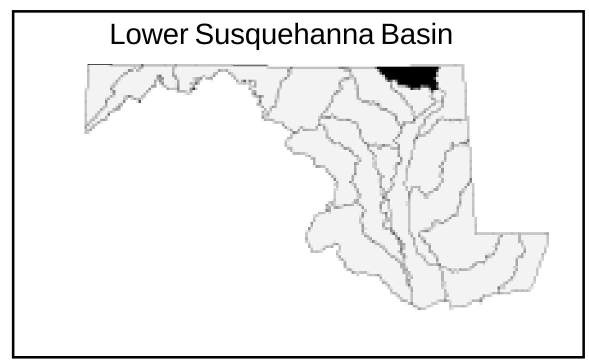




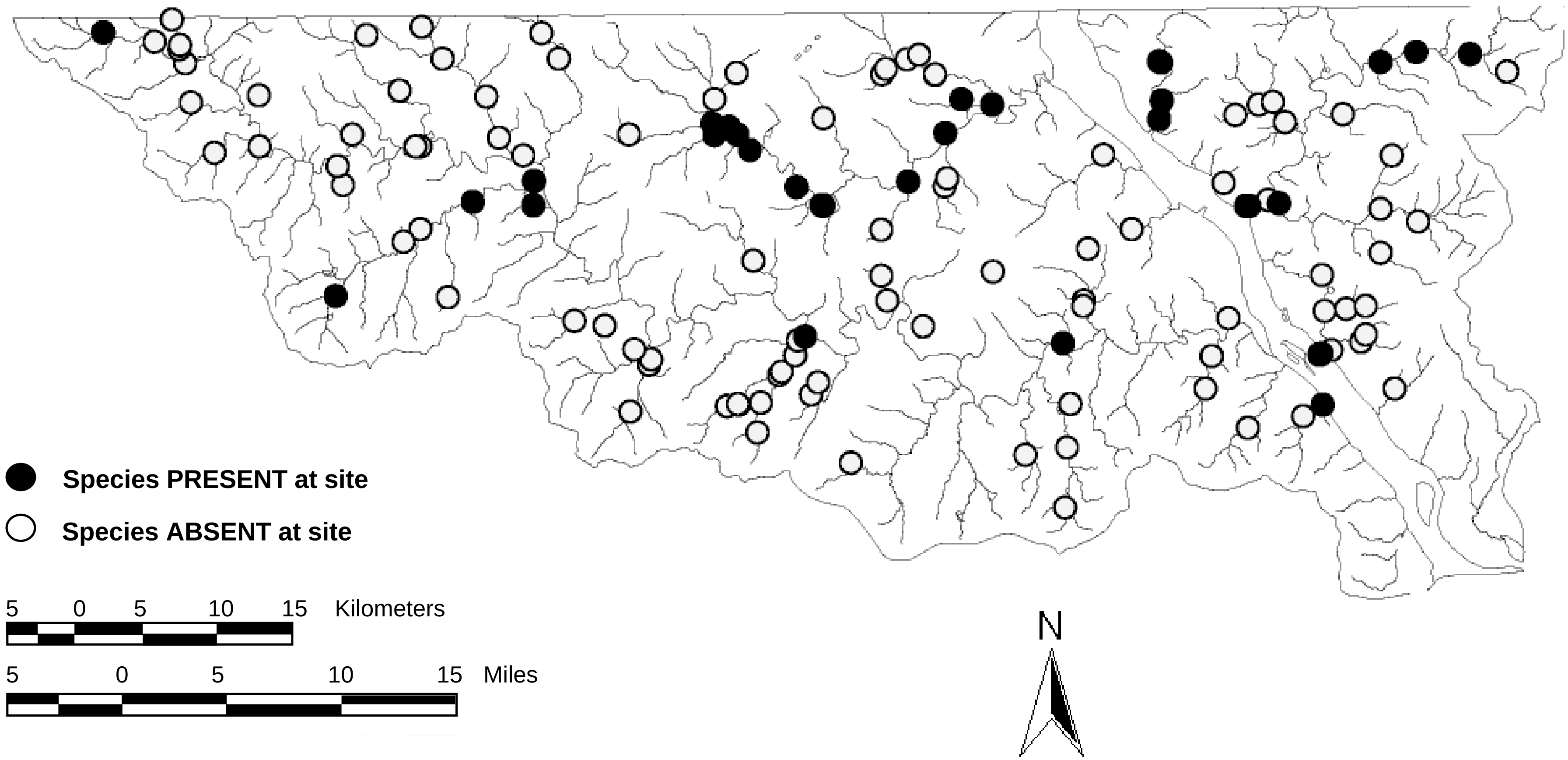
Distribution of redbreast sunfish in the Lower Susquehanna basin, 1994 and 1997.

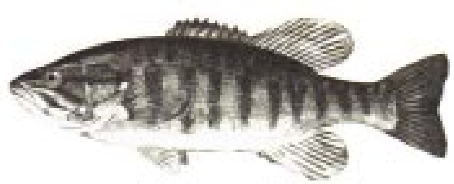


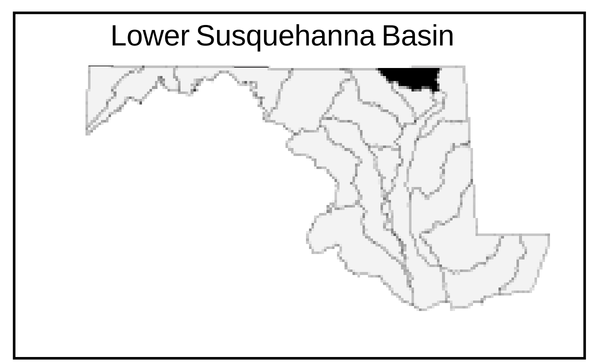




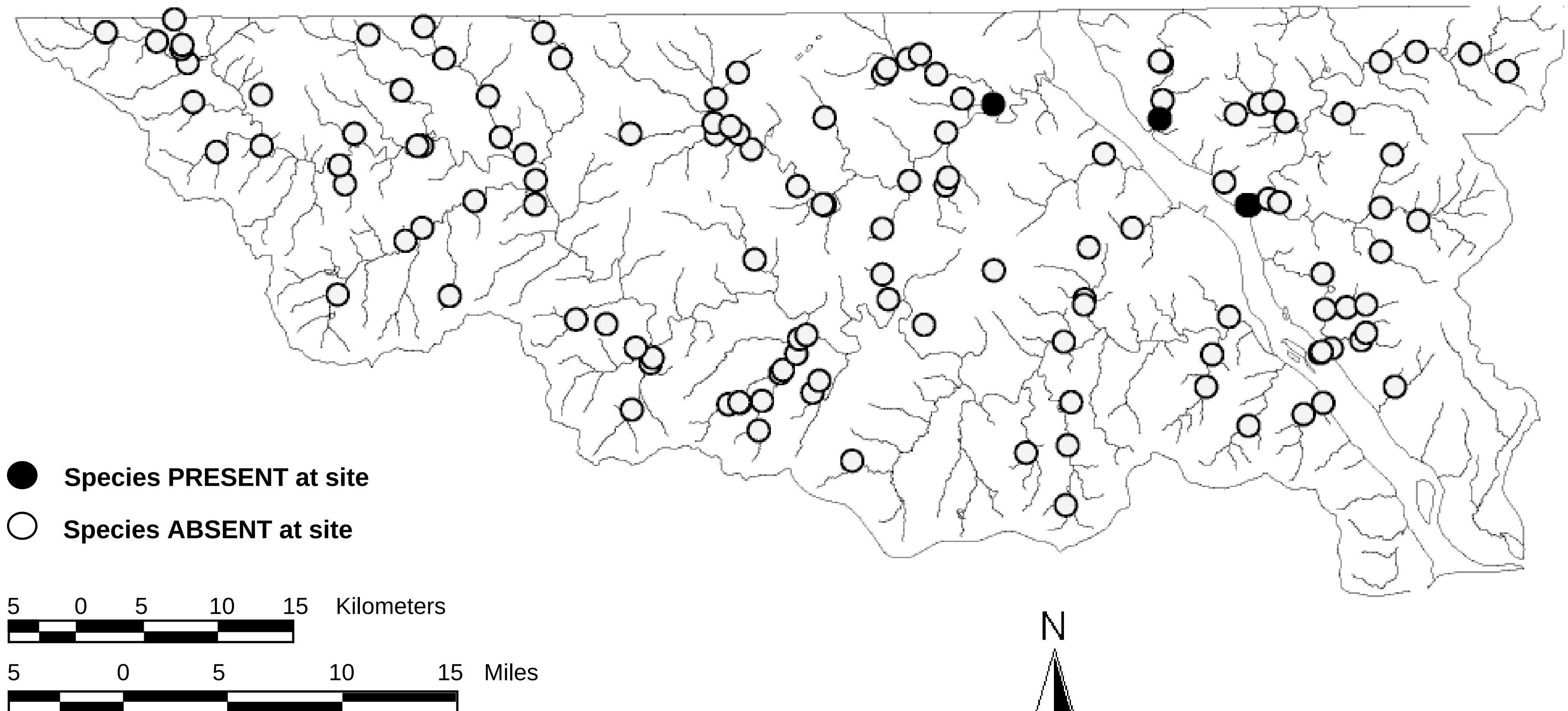
Distribution of rock bass in the Lower Susquehanna basin, 1994 and 1997.

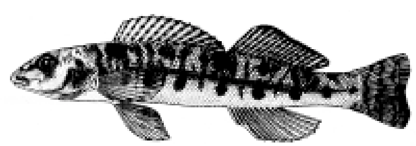


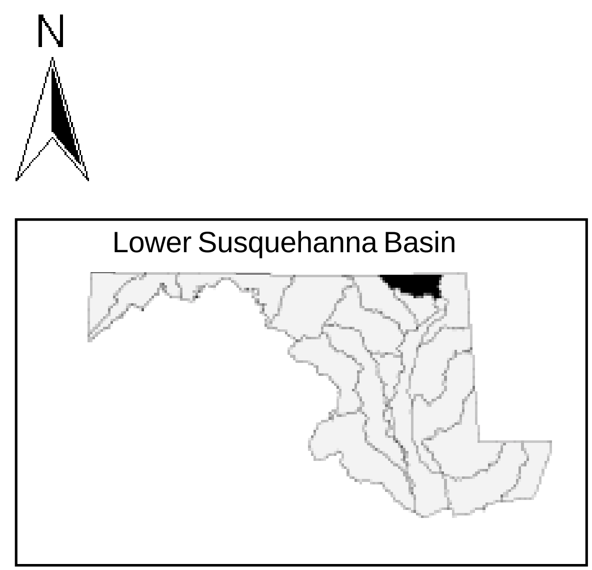




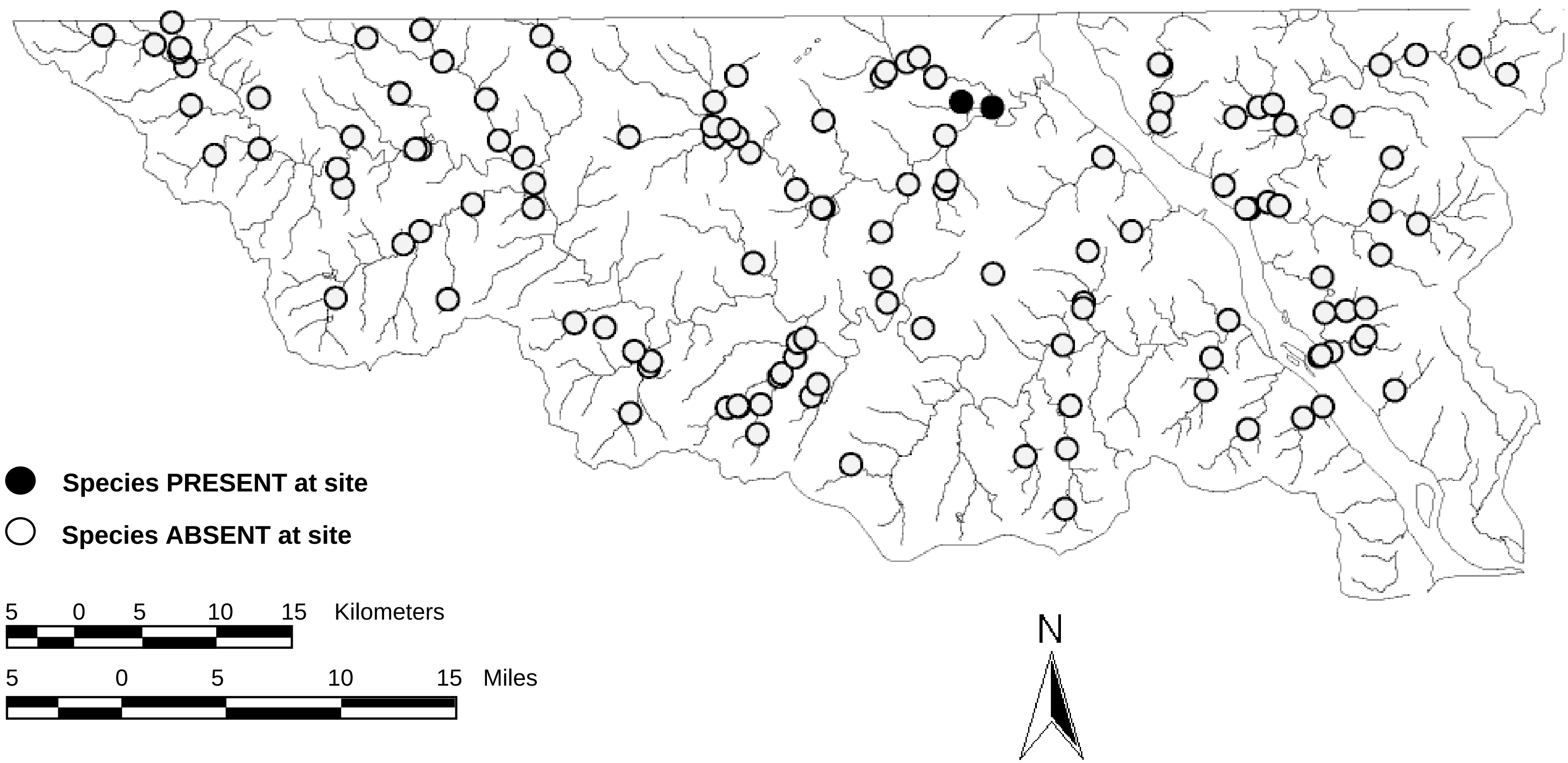
Distribution of smallmouth bass in the Lower Susquehanna basin, 1994 and 1997.

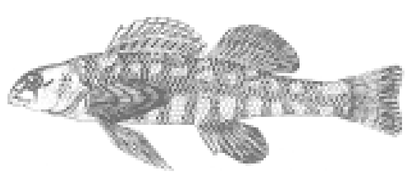


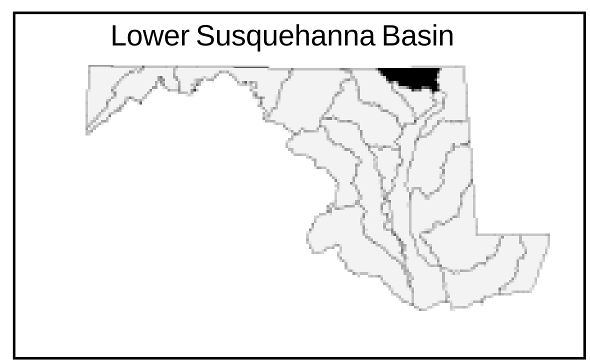




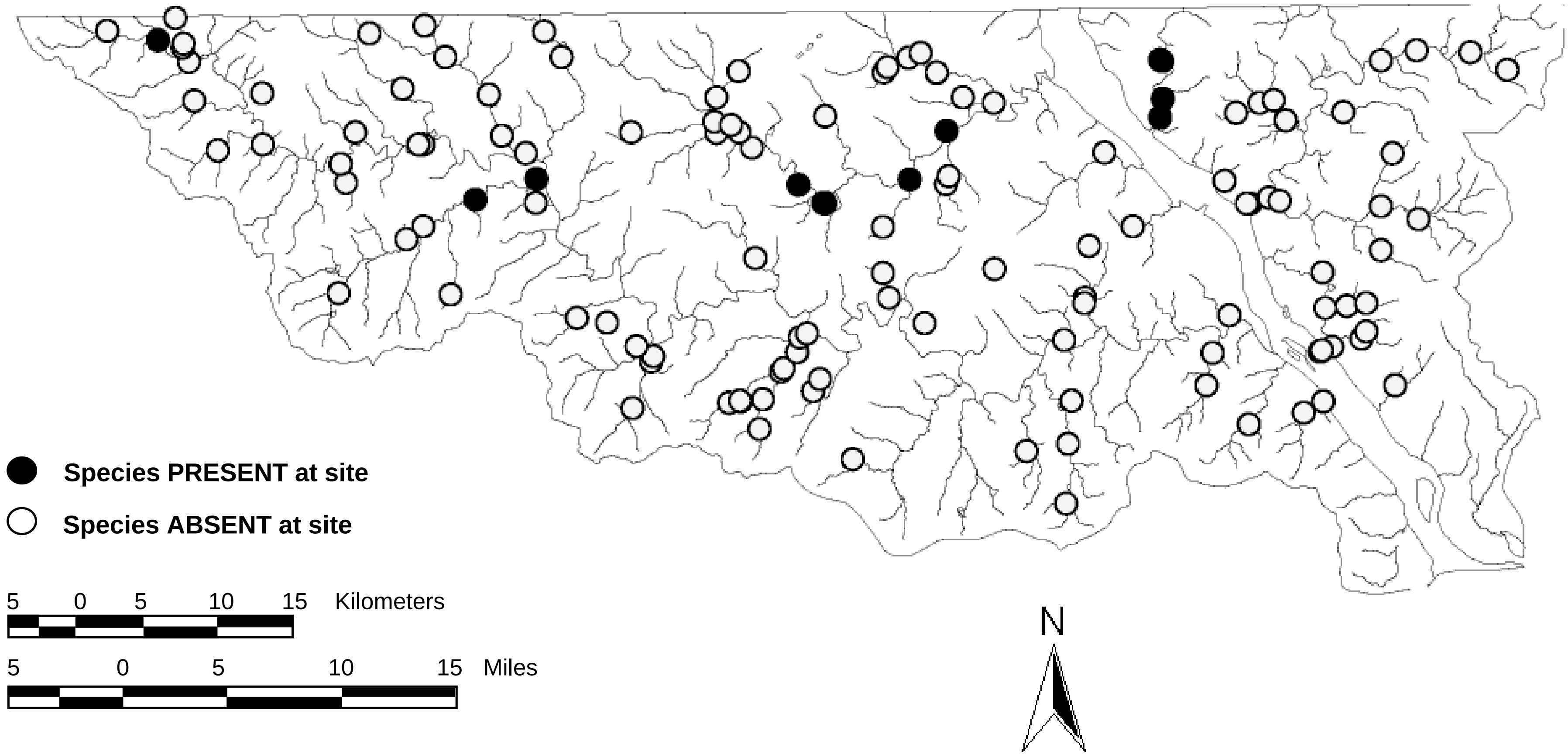
Distribution of logperch in the Lower Susquehanna basin, 1994 and 1997.

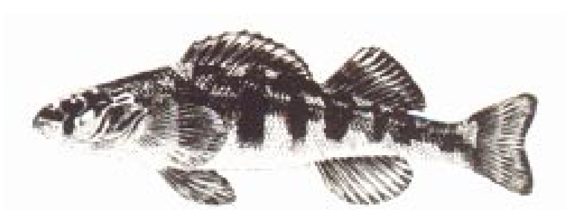


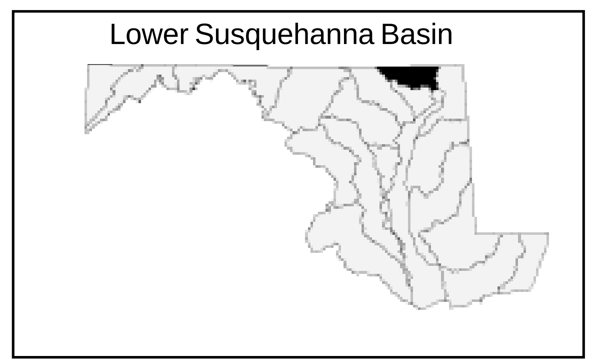




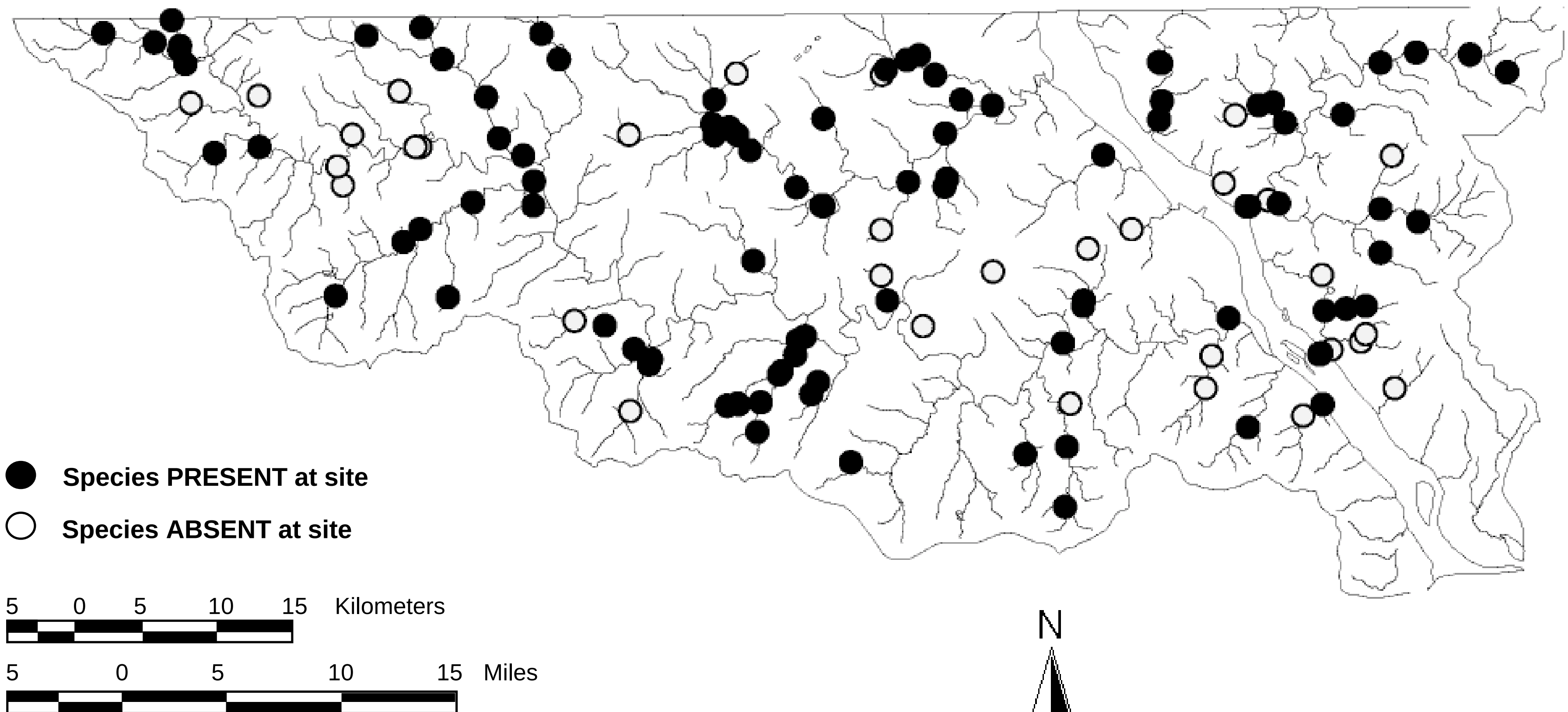
Distribution of banded darter in the Lower Susquehanna basin, 1994 and 1997.

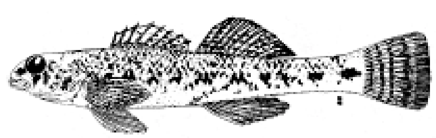


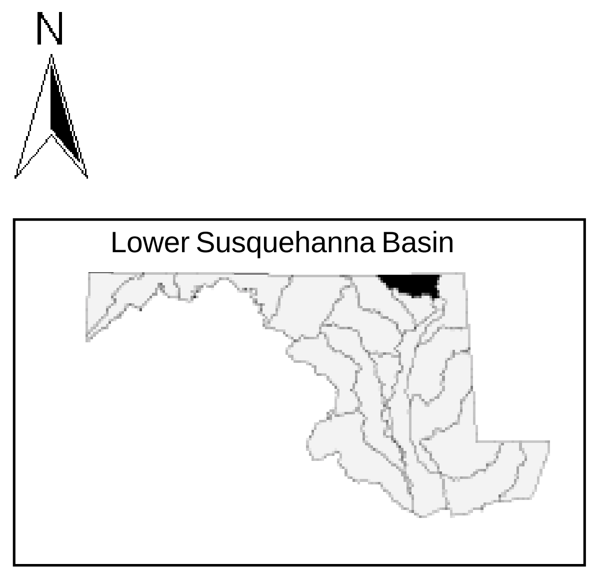




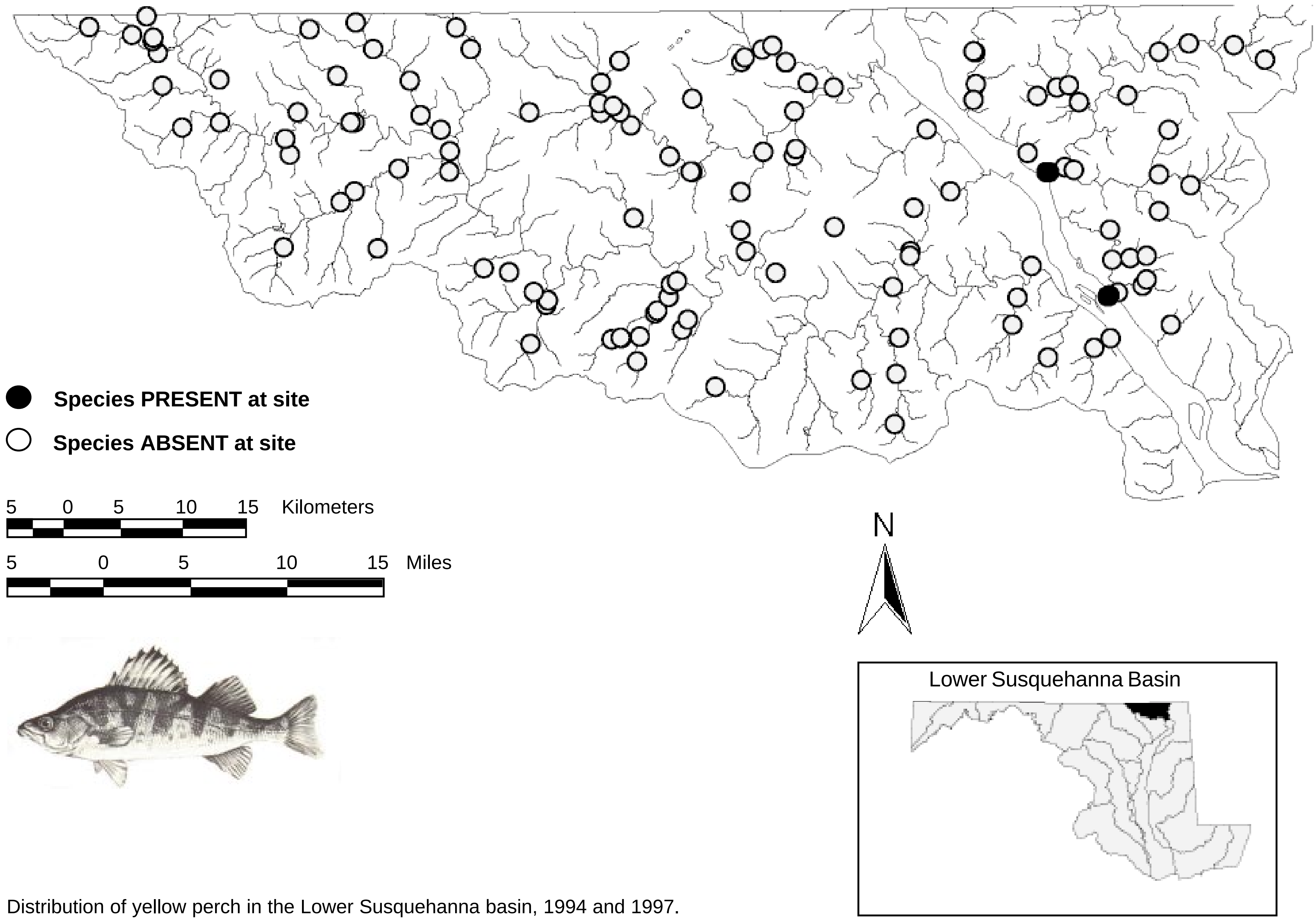
Distribution of shield darter in the Lower Susquehanna basin, 1994 and 1997.







Distribution of tesselated darter in the Lower Susquehanna basin, 1994 and 1997.



Distribution of yellow perch in the Lower Susquehanna basin, 1994 and 1997.

Appendix F. Benthic macroinvertebrate taxa with designated tolerance value (TV 10 = most tolerant, 0 = least tolerant), functional feeding groups (FFG), habit, and percent occurrence (% Occ.) for the 1997 MBSS sites in the Lower Susquehanna basin. Abbreviations of habits are as follows: bu - burrower, cn - clinger, sp - spawler, cb - climber, sw -swimmer, dv - diver, sk - skater (modified from Stribling et al. 1998)

Class	*Order*	*Family*	*Genus*	*TV*	*FFG*	*Habit*	*% Occ.*
Enopla	Hoplonemertea	Tetrastemmatidae	*Prostoma*		Predator		2.7
Turbellaria	Tricladida	Planariidae	*Cura*			sp	2.7
Oligochaeta	Lumbriculida	Lumbriculidae		10	Collector	bu	10.8
	Tubificida	Naididae		10	Collector	bu	5.4
Gastropoda	Basommatophora	Ancylidae	*Ferrissia*	7	Scraper	cb	2.7
		Planorbidae	*Helisoma*	6	Scraper	cb	2.7
Pelecypoda	Veneroida	Sphaeriidae	*Pisidium*	8	Filterer	bu	2.7
			Sphaerium	8	Filterer	bu	2.7
Malacostraca	Amphipoda	Crangonyctidae	*Crangonyx*	4	Collector	sp	13.5
		Gammaridae	*Gammarus*	6	Shredder	sp	16.2
			Stygonectes	6	Shredder	sp	5.4
Insecta	Ephemeroptera	Ameletidae	*Ameletus*	0	Collector	sw, cb	5.4
		Baetidae	*Acentrella*	4	Collector	sw, cn	2.7
			Acerpenna	4	Collector	sw, cn	10.8
			Baetis	6	Collector	sw, cb, cn	29.7
		Ephemerellidae	*Ephemerella*	2	Collector	cn, sw	86.5
			Eurylophella	4	Scraper	cn, sp	43.2
			Serratella	2	Collector	cn	16.2
		Heptageniidae	*Epeorus*	0	Scraper	cn	43.2
			Heptagenia	4	Scraper	cn, sw	16.2
			Stenacron	4	Collector	cn	5.4
			Stenonema	4	Scraper	cn	67.6
		Isonychiidae	*Isonychia*	2	Filterer	sw, cn	32.4
		Leptophlebiidae	*Leptophlebia*	4	Collector	sw, cn, sp	5.4
			Paraleptophlebia	2	Collector	sw, cn, sp	32.4
Insecta	Odonata	Calopterygidae	*Calopteryx*	6	Predator	cb	2.7
		Coenagrionidae	*Argia*	8	Predator	cn, cb, sp	2.7
		Gomphidae	*Dromogomphus*	4	Predator	bu	2.7
Insecta	Plecoptera	Chloroperlidae	*Sweltsa*		Predator	cn	5.4
		Leuctridae	*Leuctra*	0	Shredder	cn	13.5
		Nemouridae	*Amphinemura*	3	Shredder	sp, cn	35.1
			Prostoia		Shredder	sp, cn	43.2
		Perlidae	*Acroneuria*	0	Predator	cn	10.8
			Eccoptura		Predator	cn	2.7
		Perlodidae	*Isoperla*	2	Predator	cn, sp	5.4
		Pteronarcyidae	*Pteronarcys*	2	Shredder	cn, sp	2.7
		Taeniopterygidae	*Strophopteryx*		Shredder	sp, cn	8.1
Insecta	Megaloptera	Corydalidae	*Corydalus*	5	Predator	cn, cb	5.4
			Nigronia	0	Predator	cn, cb	5.4
Insecta	Trichoptera						2.7
		Glossosomatidae	*Glossosoma*	0	Scraper	cn	5.4
		Hydropsychidae	*Cheumatopsyche*	5	Filterer	cn	73.0
			Diplectrona	2	Filterer	cn	24.3
			Hydropsyche	6	Filterer	cn	73.0
		Limnephilidae	*Goera*		Scraper	cn	2.7

Class	Order	Family	Genus	TV	FFG	Habit	% Occ.
Insecta	Trichoptera	Limnephilidae	*Ironoquia*	3	Shredder	sp	2.7
			Pycnopsyche	4	Shredder	sp, cb, cn	5.4
		Odontoceridae	*Psilotreta*	0	Scraper	sp	2.7
		Philopotamidae	*Chimarra*	4	Filterer	cn	21.6
			Dolophilodes	0	Filterer	cn	10.8
		Polycentropodidae	*Polycentropus*	5	Filterer	cn	5.4
		Psychomyiidae	*Psychomyia*	2	Collector	cn	2.7
		Rhyacophilidae	*Rhyacophila*	1	Predator	cn	21.6
		Uenoidae	*Neophylax*	3	Scraper	cn	16.2
Insecta	Coleoptera	Dytiscidae	*Agabus*	5	Predator	sw, dv	2.7
			Hydroporus	5	Predator	sw, cb	2.7
		Elmidae	*Dubiraphia*	6	Scraper	cn, cb	5.4
			Macronychus	4	Scraper	cn	2.7
			Optioservus	4	Scraper	cn	45.9
			Oulimnius	2	Scraper	cn	45.9
			Promoresia	2	Scraper	cn	2.7
			Stenelmis	6	Scraper	cn	21.6
		Hydrophilidae	*Hydrobius*	5	Collector	cb, cn, sp	2.7
		Psephenidae	*Ectopria*	5	Scraper	cn	5.4
			Psephenus	4	Scraper	cn	16.2
		Ptilodactylidae	*Anchytarsus*	4	Shredder	cn	2.7
Insecta	Diptera	Ceratopogonidae	*Bezzia*	6	Predator	bu	8.1
			Ceratopogon	6	Predator	sp, bu	2.7
			Probezzia	6	Predator	bu	2.7
		Chironomidae	*Apsectrotanypus*	5	Predator	bu, sp	2.7
			Brillia	5	Shredder	bu, sp	10.8
			Cardiocladius	6	Predator	bu, cn	2.7
			Cladotanytarsus	7	Filterer		2.7
			Conchapelopia	6	Predator	sp	40.5
			Corynoneura	7	Collector	sp	8.1
			Cricotopus/ Orthocladius		Shredder		78.4
			Cryptochironomus	8	Predator	sp, bu	2.7
			Diamesinae	5	Collector	sp	2.7
			Diamesa	5	Collector	sp	43.2
			Diplocladius	7	Collector	sp	2.7
			Eukiefferiella	8	Collector	sp	62.2
			Heleniella		Predator	sp	2.7
			Heterotrissocladius		Collector	sp, bu	2.7
			Hydrobaenus	8	Scraper	sp	8.1
			Larsia	6	Predator	sp	2.7
			Micropsectra	7	Collector	cb, sp	16.2
			Microtendipes	6	Filterer	cn	18.9
			Nanocladius	3	Collector	sp	5.4
			Orthocladiinae A	6	Collector	sp, bu	10.8
			Orthocladius	6	Collector	sp, bu	24.3
			Parametriocnemus	5	Collector	sp	56.8
			Paratanytarsus	6	Collector	sp	8.1
			Polypedilum	6	Shredder	cb, cn	37.8

Class	***Order***	***Family***	***Genus***	***TV***	***FFG***	***Habit***	***% Occ.***
Insecta	Diptera	Chironomidae	*Rheotanytarsus*	6	Filterer	cn	27.0
			Sublettea		Collector		16.2
			Sympotthastia	2	Collector	sp	18.9
			Tanytarsus	6	Filterer	cb, cn	24.3
			Thienemanniella	6	Collector	sp	21.6
			Thienemannimyia		Predator	sp	16.2
			Trissopelopia		Predator	sp	5.4
			Tvetenia	5	Collector	sp	10.8
			Unniella		Collector		2.7
			Zavrelia	4	Collector	cb, sp, cn	8.1
		Empididae	*Chelifera*		Predator	sp, bu	16.2
			Clinocera		Predator	cn	29.7
			Hemerodromia	6	Predator	sp, bu	56.8
		Muscidae	*Limnophora*		Predator	bu	2.7
		Simuliidae	*Cnephia*	4	Filterer	cn	2.7
			Prosimulium	7	Filterer	cn	75.7
			Simulium	7	Filterer	cn	24.3
			Stegopterna	7	Filterer	cn	8.1
		Tabanidae	*Chrysops*	7	Predator	sp, bu	2.7
		Tipulidae	*Antocha*	5	Collector	cn	51.4
			Dicranota	4	Predator	sp, bu	13.5
			Limonia	6	Shredder	bu, sp	5.4
			Tipula	4	Shredder	bu	5.4